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A carbon neutral campus. Tools of carbon footprint and handprint assessment.

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ABSTRACT

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The goal of this thesis project was to provide the groundwork for the calculation of the carbon footprint of the University of Oulu and formulate recommendations for best applicable methodologies. The work includes a literature review on the concept of carbon neutrality and its importance in the context of climate change and related international treaties and pledges. This is combined with research on the connection between net zero emissions, carbon footprint and handprint, as well as the most commonly used standards and guidelines for assessing emissions caused by an organisation or a product.

Further, the carbon footprint calculations conducted by 16 higher education institutions were reviewed. This review analysed the categories chosen in the carbon footprint assessment, the standard utilised, the methodology applied, the categories of emissions included, as well as the benefits and limitation identified during the calculation process.

It was found that, while there are existing standards and guidelines for the calculation of organisational carbon footprints, the specific cases presented by universities were not supported by a specifically prepared guideline, leading to a variety of approaches used. The analysis also showed that, depending on the scopes of emissions, it is possible to discern the favoured methodologies. Emissions related to energy consumption, as well as direct emissions, are more often calculated based on activity data and emission factors considered in life-cycle assessment, while indirect emissions related to procurements and the purchase of equipment are often determined using financial information based on the proceedings of input-output analysis. In addition, it was discovered that indirect emissions included vary strongly between the assessed institutions. The most popular categories were business travels, commuting, food, procurement and equipment, as well as emissions related to waste management and the maintenance of the property.

The results presented in this work can be utilised to support the ongoing carbon footprint calculation process of the University of Oulu. The results also help in recognising the differences between various approaches and point out the necessity of creating a common framework for the assessment of emissions of higher education institutions.

Keywords: carbon footprint, carbon neutrality, carbon handprint, greenhouse gas emissions

FOREWORD

This master's thesis was done as preparatory work and support for the currently ongoing calculation of the carbon footprint at the University of Oulu. The goal was to establish a common framework to help the carbon footprint working group deciding on the best practices and methods when assessing the situation at the university. The working period for the thesis was from January 2021 until May 2021, supervised by Prof. Eva Pongrácz and Prof. Maria Kopsakangas-Savolainen.

I would like to especially thank my two supervisors, Eva and Maria, who helped me in developing this thesis and encouraged me along the way. My gratitude also goes to Meeri Hilli for the insight she provided in the ongoing calculation work at the university.

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Oulu, 03.05.2021

Julia Kiehle

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LIST OF ABBREVIATIONS

BSI	British Standards Institution
CCS	Carbon Capture Storage
CFP	Carbon Footprint
CHP	Combined Heat and Power
CO_2e	Carbon Dioxide Equivalents
COP	Conference of the Parties
EEIOA	Environmentally Extended Input-Output Analysis
ETS	Emission Trading System
EU	European Union
GHG	Greenhouse Gas
GWP	Global Warming Potential
HFC	Hydrofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
IOA	Input-Output Analysis
ISO	International Standardisation Organisation
LCA	Life-Cycle Assessment
NDC	Nationally Determined Contribution
NECP	National Energy and Climate Plan
PAS	Publicly Available Specification
PFC	Perfluorinated Compound
PV	Photovoltaic
SDG	Sustainable Development Goal
SYK	Suomen Yliopistokiinteistöt Oy (engl. University Properties of Finland Ltd.)
SYKE	Suomen Ympäristökeskus (engl. Finnish Environment Institute)
TÜV	Technischer Überwachungsverein (engl. Technical Inspection Association)
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

GLOSSARY

Carbon negative	In contrast to carbon neutrality where the goal is the net balance of emissions, this term describes the situation when the removed or absorbed emissions outweigh the emitted ones.
Carbon neutrality	A popular term for achieving net zero carbon emissions by balancing the amount of emitted greenhouse gas emissions with the amount of absorbed emissions in a certain time frame and for specific system.
Clean energy	A term for energy sources which in contrast to fossil fuels are not emitting high amounts of emissions.
Climate neutrality	A synonym for carbon neutrality.
CO_2 equivalents	An expression that sums up all greenhouse gas emissions but converted to carbon dioxide according to the relation of their global warming potentials.
Decarbonisation	The process that leads to the achievement of carbon neutrality, encompassing all measures and actions undertaken, such as the implementation of policies, the switch towards fossil fuel-free energy sources or low-carbon technologies.
Deep decarbonisation	A form of decarbonisation that requires extensive structural or systematic changes.
Fossil-free	A term used in the energy sector signifying the utilisation of energy sources that do not emit any emissions, mainly referring to renewable energy sources such as wind, solar power, biomass and hydropower.
Greenhouse gas	A gas that plays a key role in causing climate change due to its global warming potential. Examples are carbon dioxide, methane, nitrous oxides, and fluorocarbons.
Low-carbon	A term mainly utilised for the characterisation of technologies that do not produce emissions or at least cause less emissions than a comparable process.

1 INTRODUCTION

Reducing greenhouse gas emissions and decarbonising the society became a broadly discussed topic in recent years. In the light of the ongoing climate change, achieving carbon neutrality is one of the most important steps the global community has to take to stop the repercussions of global warming from dramatically worsen. Some of the main consequences associated with climate change include the rising of the global temperature level and the therefrom resulting melting ice caps, increasing sea levels and the raised frequency of extreme weather incidents. In 2018, the Intergovernmental Panel on Climate Change (IPCC) released a special report about the altering climate indicating that the global warming process already led to an increase by around 1°C compared to the temperature level before the industrialisation. If this trend is not slowed down or stopped, a temperature rise of 1.5°C could be reached as early as 2030. (IPCC, 2018) According to the Paris Agreement, the international treaty signed in 2015 with the goal to combat climate change, 1.5°C is the preferred limit under which the global warming should be kept regarding the habitability of the planet, with 2°C being the uppermost limitation. (UNFCCC, 2021b)

The main contributor behind the climate change is the increased concentration of greenhouse gases in the atmosphere caused by human activity. Despite international agreements and the clear warnings of experts that the difference between an anthropogenic global warming of 1.5°C or 2°C can be severe for biodiversity, ecosystems, the climate system and human lives (IPCC, 2018), the global emission rate is still on an upward swing. The European Union (EU) belongs to the highest emitters of carbon emissions around the world and while there was a slight declining trend in its emissions in recent years (Crippa et al., 2020), it might not be enough to keep in line with the goal of the Paris Agreement if not more actions are taken.

The mitigation of greenhouse gas emissions is identified as one of the most important things to do to hamper the ongoing global warming (IPCC, 2014, 2018). As stated by the European Parliament (2019), there is a large gap between the sequestration ability of natural carbon sinks and the amount of emissions released globally. Scientists state that the global warming potential currently sums up to about 0.2°C per decade. The higher the temperature rises, the more difficulties will occur, including the threats posed by sea level rising, effects on the biodiversity and the development of the weather and weather extremes. (IPCC, 2018) The latter is not something that is only happening in faraway places, like the melting of ice in Arctic and Antarctica or droughts in Central Africa, but can also be witnessed in European countries like Finland, where receding ice and snow covers, as well as milder than usual temperatures during winter were clearly observed (Dahal & Niemelä, 2016).

Nowadays, reaching carbon neutrality is implemented as goal by more and more organisations, institutions, countries, and other association on national and international level to combat the ensuing problems of the climate change. The European Union pledged in the new European Green Deal to achieve net zero emissions by 2050 (European Union, 2019a), laying out the pathway for all its member states. In accordance with that goal, a working group of Finnish Universities published a number of theses for a sustainable future of higher education institutes in Finland including the recommendation to realise carbon neutrality in 2030 and act as forerunners in this area (UNIFI, 2020). To support those goals, it is necessary to rely on appropriate measurement tools for assessing the rate of emissions, like the carbon footprint (CFP) and carbon handprint.

The objective of this thesis work is to build a foundation for the University of Oulu on its own way to carbon neutrality by providing an overview of the topic and assessing the best way to proceed in terms of calculating a carbon footprint for the institution. In relation to that, there are three main research questions that will be investigated:

1) What is the carbon footprint and how is it utilised as tool of carbon neutrality?
2) What is the carbon handprint and how is it connected to the carbon footprint?
3) What is the best approach for calculating the carbon footprint of a higher education institution, in general and specifically of the University of Oulu?

This thesis project will first highlight the meaning behind carbon neutrality, including the general concept, offsetting practices for emissions and international decarbonisation pledges, as well as national climate policies in Finland. Furthermore, the possibilities to assess the carbon intensity of actions and processes will be analysed. The focus there is on calculation methods and preferred guidelines for the carbon footprint assessment. As it is offering an alternative approach for the analysis of emissions, the concept of the carbon handprint is explored in relation to the carbon footprint. In addition, being identified as potential leaders in achieving carbon neutrality, the approaches of different universities for developing a carbon neutral campus are investigated as starting point for the experimental part of the thesis work.

In accordance with the adoption of specific timelines and goals for reducing emissions it is important to agree upon the most appropriate practices in terms of measurement tools and calculation methods. To ensure a fast-proceeding implementation of a carbon footprint assessment in the daily proceedings of a university it is also necessary to include stakeholders and expert working groups in the decision process. In the second part of this thesis work, an analysis of existing calculation methods and approaches from universities around the world, with a special focus on Finnish universities, will be conducted based on previously chosen criteria. Those will be presented in the methodology chapter of the thesis. The assessment will result in recommendations for a calculation approach at the University of Oulu, tackling the questions what kind of emissions should be included in the carbon footprint of a campus and which calculation method might be the most beneficial to use. Finally, the current situation of the ongoing calculation process at the University is evaluated in relation to the identified recommendations. In addition, ideas for mitigation measures related to greenhouse gas emissions are presented based on approaches introduced by other higher education institutions.

The ultimate goal of this work is to provide a starting point for further actions towards a carbon neutral campus at the University of Oulu by providing background information based on a literature review and the analysation of already applied assessment methods.

2 CARBON NEUTRALITY

The terms carbon neutral or carbon neutrality are widely used in relation to efforts of combating climate change. They come up in discussions for mitigating emissions in various sectors of economy and society, ranging from energy-related topics to labelling food products, and are also mentioned as goals in international treaties and climate action plans of countries, companies, or organisation. In the following, the general concept behind the terms is analysed, as well as the meaning of related expressions. In addition, the practices of offsetting emissions in relation to carbon neutrality are presented. In that way, the chapter will provide a basis for the remaining work of this thesis.

2.1 General idea and concept of carbon neutrality

2.1.1 Net zero carbon emissions

The basic idea underlying many definitions for carbon neutrality is the fact that the object of investigation would have net zero carbon emissions. This means that the amount of emitted carbon is balanced with the amount of absorbed emissions in a certain time frame and applied to a specific system with defined boundaries (European Parliament, 2019). This could be for example a product and its life cycle or an organisation with all its ongoing operations. The system includes all relevant flows and processes associated with the product or the organisation that are necessary to perform a previously specified function (ISO, 2006).

The emissions can be sequestered in natural carbon sinks or via carbon capture methods. The former refers to a system able to predominantly absorb carbon instead of only emitting emissions; examples are forests or the oceans (European Parliament, 2019). The other option refers to the carbon capture storage (CCS) processes, where emissions are removed directly at the point of their formation (e.g. during combustion of fossil fuels) and bound in different ways to ensure that they won't be released into the atmosphere. One of the preferred storage or sequestration options is the injection of the gas in suitable geological formations. (Smit et al., 2014, pp. 2–4) In addition to this direct method of sequestration, the utilisation of natural carbon sinks is referred to as the indirect method, as it is based on naturally occurring chemical or biological processes (Kowalska et al., 2020). It is also possible to influence the indirect sequestration by enhancing the performance of the natural carbon sinks, for example by proper forestry management (Herzog & Golomb, 2004).

In addition to the removal and sequestration of emissions, the definition of carbon neutrality also often includes the possibility to achieve the net balance by offsetting emission. In general, carbon offsets are compensations that are bought from someone and somewhere else but counted as reduced carbon emissions for the buyer. Settled against the caused emissions, the offsets allow the achievement of a net-zero balance. Offsetting programmes include for example afforestation activities, but also the financial support of renewable energy projects. (European Parliament, 2019) Figure 1 presents a visualisation of this aspect.

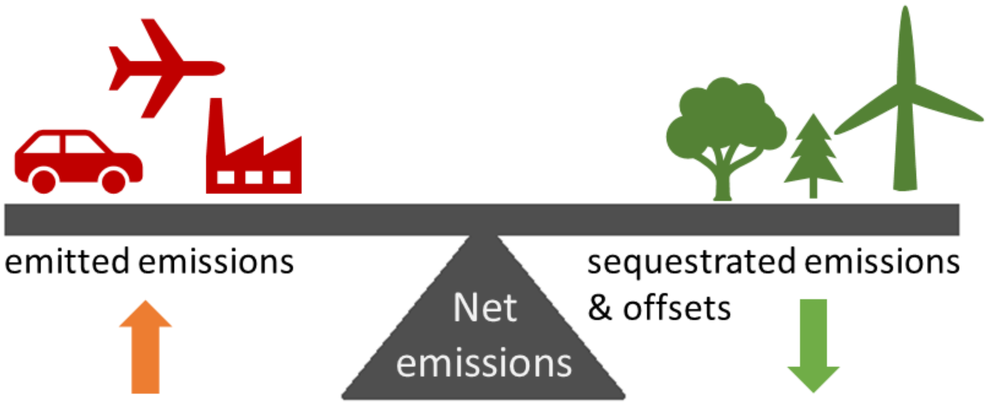

Figure 1. Visualisation of net zero carbon emissions.

2.1.2 The scope of carbon neutrality

Depending on the scale, a net balance between emitting carbon emissions and the directly or indirectly absorbed amount of carbon needs to be achieved for all ongoing procedures belonging to the object of investigation. Considering the climate change and international treaties such as the Paris Agreement, the overall goal is carbon neutrality for the whole world. However, it can also be aimed for on a smaller scale - for individual companies and organisations or countries and municipalities, as well as simply for a single product. The system boundary and the function presented by the system will change in accordance with the scale set by the object of investigation. A country, for instance, will have to include all sectors of its economy, like industry, transportation, or energy generation, as well as the remaining emissions associated with the functioning of society to present a complete assessment of its emissions. Long-term roadmaps and action plans featuring mitigation measures are frequently used tools implemented to reach carbon neutrality. This aspect is for example supported by the climate and energy policies introduced by the European Union (Amanatidis, 2019), which will be presented in more detail later on. In contrast, organisations and companies are able to focus their efforts also on short-term solutions featuring offsetting measures to account for their individual emissions, only related to their own operations without the inclusion of large-scale national emission rates. The same can also be done for one product or one event where the system boundary strictly limits the scope to emissions relevant enough for this single object to be accounted in its inventory. The difference of required actions and the nature of goals related to carbon neutrality is further addressed in accordance with official commitments and when the various guidelines for assessing the emissions are introduced.

The nature of the different scales to which the concept of carbon neutrality can be applied leads to the appearance of the issue regarding the allocation of emissions. When assessed systems are overlapping or the objects of investigation are including the same operations and processes, it is necessary to decide to whom the ensuing emissions will be counted. Allocation is a term from the guidelines for Life-Cycle Assessment (LCA) and describes the procedure that provides the option to define which flow of emissions or which share of the total amount belongs to the analysed system. (ISO, 2006) Allocating emissions is especially relevant for smaller scales, like companies, when the borders of their operations are not as clearly to define, but it also plays a role on higher levels.

2.1.3 Definition of relevant terms

The usage of the term carbon neutrality might lead to the misconception that there is a focus on only carbon dioxide (CO_2) emissions when aiming for the net zero balance, which is in general not the case (Dahal & Niemelä, 2016). In addition to carbon dioxide, the gas with the highest impact rate, there are other relevant gases who are playing a key role in causing climate change, such as methane, nitrous oxides, and fluorocarbons (HFC and PFC), summed up as greenhouse gases (GHG) (IPCC, 2014). The term carbon neutrality is often used in a way that includes all relevant emissions, making CO_2 only the representative of all the greenhouse gases. This practice will also be applied to this thesis. In emission inventories, the usage of 'CO_2 equivalents' reflects this definition as well. Subsequently, the preferred unit for presenting emissions is the mass unit of tonnes of CO_2 equivalents (Pandey et al., 2011).

In their analysis of carbon neutrality in an urban context, Tozer & Klenk (2018) came to the conclusion that while the main goal of carbon neutrality seems to be the same, the phrasing can vary between different application areas. Terms like ‘climate neutral’, ‘fossil fuel-free’, ‘clean’, ‘low-carbon’ and ‘carbon neutral’, as well as ‘(deep) decarbonisation’ all refer to the reduction or balancing of greenhouse gas emissions.

Climate neutrality is a term that is often used as direct synonym for carbon neutrality, as can be seen, for example, in publications of the European Union (e.g. European Union, 2019a, 2019b), but also in research papers on the topic as found by Tozer & Klenk (2018) or Salvia et al. (2021).

Fossil fuel-free and clean are, in contrast, mainly applied in relation to the energy sector. In that context it symbolises the utilisation of energy sources that do not emit any GHG emissions while for example generating electricity or heat. Mostly this means renewable energy sources such as wind, solar power, and hydropower. The term ‘clean energy’ comes mainly from the fact that the fossil fuels (crude oil, coal and natural gas) are called ‘dirty’ (Shinn, 2018), due to them being derived from decayed organic materials and consisting of hydrocarbons that will split during combustion resulting in emitting high amounts of GHG emissions (Kiang, 2018).

Used in a similar capacity to fossil fuel-free and clean is the term ‘low-carbon’. It basically refers to producing no emissions or at least less emissions than a baseline process and is mainly used in combination with the mentioning of technologies (for example by European Parliament, 2019). Low-carbon technologies are some of the most prominent aspects when pathways towards carbon neutrality are developed (Hildingsson et al., 2019).

While most of the former terms are describing the characteristics of procedures, pathways, or technologies, ‘decarbonisation’ is the term used to refer to the process that leads to the end goal of carbon neutrality. The term includes all measures undertaken to make the object of investigation, be it country or a singular product, climate neutral: the implementation of policies, the switch towards fossil fuel-free energy sources or low-carbon technologies, among others. (Hildingsson et al., 2019) More superficial or small-scale actions are simply depicted as ‘decarbonisation’, but as soon as a scenario requires extensive structural or systematic changes the term ‘deep decarbonisation’ is preferably used (Hildingsson et al., 2019; Spencer et al., 2017). An example for a decarbonisation scenario is the switching of a company to renewable energy for their operation, whereas the restructuring of a whole energy system of a nation to make it climate neutral could be referred to as deep decarbonisation. The term is also used in relation to long-term strategies for reaching carbon neutrality (Spencer et al., 2017).

2.1.4 Approaches on how to achieve carbon neutrality

Following the definition of the term 'carbon neutrality' as the net zero balance of GHG emissions for a certain system, the pathway towards this goal consists of first accounting and managing the systems own emissions and secondly countermeasure their impact. The latter can be based on mitigation strategies to lower the initial amount of emissions, the utilisation of carbon sequestration methods and partly investing in carbon offsetting projects. Which approach is best suited to achieve carbon neutrality strongly depends on the scale of the system and how its boundaries are defined. Mitigation strategies can for example include the declaration of certain budgets for emitting carbon emissions over a certain period or shifting towards 100% renewable energy. (Tozer & Klenk, 2018) In addition to having a clear end goal, the initial characteristic of the system has a considerable influence on the suitable approach towards carbon neutrality as well (Tozer & Klenk, 2018). Looking on the country-scale, a developed country will have to invoke different measures than a developing country based on accessibility to mitigation measures, technologies, and environmental conditions. For small-scale approaches of organisations and companies the pathways depend on the nature of their business. Industrial companies with a high energy consumption will have a different focus point than for instance service-based organisations. It can be said that the planned measures are influenced by the main emitters of the analysed system.

In the context of aiming for carbon neutrality the focus can be on technological developments, economic models (e.g. emission trading schemes), energy efficiency or the behaviour of the people, like customers or citizens, depending on who is the main driver for the emissions reduction. (Tozer & Klenk, 2018) Pilpola et al. (2019) analysed for example potential methods for Finland on a country- and municipality-scale with focus on the energy system, therefore favouring a technology-based approach. The preferred pathways then feature thoughts about climate-friendly vehicles, renewable energies, or space heating concerns. The nature of the favoured approaches mainly depends on the chosen focus points and will vary in accordance with what the achievement is supposed to look like in detail. The main target on such a scale is often the reduction of emissions caused by energy-related processes similar to the research by Pilpola et al. (2019). Despite the fact that this pathway would acknowledge only parts of the whole economy or society and omitting other relevant approaches, a closer analyses done by Gil & Bernado (2020) supports the notion to favour energy-related emissions when first establishing approaches to become carbon neutral, especially for countries and cities. Because as they pointed out, around 10% of the global GHG emissions are caused by the member states of the European Union and approximately three-fourths of that amount is energy-related. (Gil & Bernardo, 2020)

The current research is not favouring one method over the other, however, the importance of energy-related approaches is repeatedly addressed. Developing action plans on various scales is not seen as following a uniform, simple solution for reaching carbon neutrality but as being tailored to fit local characteristics and the nature of the featured processes. Different challenges and focus points exist for different regions, areas, and countries, as well as organisations and involved stakeholders. The term carbon neutrality in its flexibility is inviting many different approaches, but all with the definite end goal of reducing carbon emissions. (Pilpola et al., 2019) This aspect is one of the reasons for the variety of national and international pledges, commitments, as well as climate and energy policies, that feature different approaches depending on who is the one aiming for carbon neutrality.

2.2 Offsetting emissions for carbon neutrality

2.2.1 Concept behind offsetting practices

In addition to introducing mitigation measures to reduce the amount of emitted GHG emissions, there is another option on the path towards carbon neutrality: Offsetting. Settled against the caused emissions, the offsets or compensation payments allow the achievement of a net-zero balance. (European Parliament, 2019) Such payments can include supporting forestry programs for carbon sequestration (e.g. afforestation, reforestation and preservation (van Kooten, 2017)), renewable energy and energy efficiency projects, as well as for example programs for supporting methane-to-energy technologies or the usage of biomass (Cames et al., 2016). The main idea behind offsets is that the amount of greenhouse gases in the atmosphere is handled on a global scale. In consequence, it does not matter where the emissions are released, the whole world will be affected by them. Therefore, it would also not matter globally where on earth the emissions are mitigated or sequestrated, leading to the possibility to compensate one's own emissions by paying for a mitigation somewhere else. (Anderson & Bernauer, 2016) The basic approach on how to utilise offsets for reaching net zero balance of emissions starts with the calculation of an emission inventory. The amount of released GHG emissions equals then the amount of bought offsets from an offsetting provider, cancelling out the buyer's caused emissions. (see for example Gold Standard, 2021)

Offsetting can be managed via official trading schemes like the European Emission Trading System (ETS), which is especially used for compulsory offsets (European Parliament, 2019), or via trading places like the Voluntary Carbon Market (VCM) (Greenberg & Fang, 2015). When the emission reduction that was offered by a project is bought by another entity, it is entered on a registry; an arrangement to prevent double usage. Nowadays there are international rules that apply to the procedure of offering and buying carbon offsets, for example issued by the UN, and also guidelines for verifying the associated offsetting programs, which are then for example listed as credited carbon offset projects by United Nations Framework Convention on Climate Change (UNFCCC). (ClimateCare, 2021) In addition to being issued from a verifiable program, the project claiming to reduce emissions, needs to prove that it was set up following a strict set of rules. First of all, the project has to make sure that the promised emission reduction is permanent. Furthermore, emission shifting and emitting more emissions than the project promises to reduce are forbidden (also described as carbon leakage (Peterson St-Laurent et al., 2017)). At last, only projects offering additional reduction measures are allowed. (Childs, 2020) This rule is often referred to as 'additionality' (e.g. Mason & Plantinga, 2013) and is subject of much discussion and uncertainty. In detail it means, that the payments made by the companies wishing to offset emissions provide the funding that enables the realisation of the project. Without those payments, the project would not have happened because it would not have been feasible from an economic or technological point of view. (Peterson St-Laurent et al., 2017)

2.2.2 Benefits and drawbacks related to carbon offsetting

One of the key benefits associated with the usage of carbon offsets is the aspect of time and progress. If the funded projects are verified and keep what they are promising, meaning sequestration or reduction of emissions, then they provide a quick and cost-effective way to mitigate the impacts of climate change. At least until companies and organisations are able to reduce their initial emissions to zero or close to it, the offsets offer the possibility to already do something now to become more climate friendly. From that perspective, compensating carbon emissions might grant some additional time to enhance the necessary emission mitigations. (Niiler, 2020; UNEP, 2019)

Some drawbacks on the other hand include the complexity of setting a price for the emission reduction per tonne of CO_2 equivalents (Greenberg & Fang, 2015) and the difficulties associated with proving that the nature of the project is additional and permanent. The latter is especially true for forestation programs due to the uncertainty that comes with managing a forest (Peterson St-Laurent et al., 2017). This shows that the benefits and drawbacks clearly depend on the characteristic of the different kinds of offsetting projects. It is pointed out by different analyses that the main point for effectiveness and acceptance of offsetting measures is transparency and the upholding of standards in relation to the offsetting markets, projects and practices (Anderson & Bernauer, 2016). The critical assessment boils down to the point that carbon offsetting needs to be verified by a third party (Niiler, 2020) and the long-term ability to reduce emissions has to be ensured, increasing the trustworthiness of the projects (van Kooten, 2017).

2.2.3 Critical opinions about offsetting emissions

The opinion about whether the utilisation of offsetting practices should be allowed or not when aiming for carbon neutrality differs a lot, even already in the early theoretical approaches on the subject. Those analyses of carbon neutrality come to different conclusions: In contrast to Bookhart (2008), who does not encourage the use of compensation payments after analysing different strategies for reaching carbon neutrality, Willson & Brown (2008), based on their assessment of carbon neutrality in a local context, would also favour the utilisation of carbon offset payments, as they can be economical advantageous compared to other capital investments undertaken by the responsible party. The main critic point brought forth by Bookhart (2008) is the neglect of other, simultaneously emitted pollutants that are not counted as GHG emissions. Offsetting measures are often not carried out in the same geographical region as where the one paying for the offset is located. This still results in a global mitigation of carbon emissions but counteracts the opportunity to handle local environmental impacts caused by other emissions or pollutants. A similar discussion can also be detected as part of the more recent research. While Barker & Crawford-Brown (2015, p. 127) remain sceptically about the achievable effects of carbon offsetting in their assessment of mitigation policies, Laine et al. (2020) promote the usage of compensation measures for cities trying to reach carbon neutrality after analysing various pathways for decarbonisation on that level. They argue that this would make the goal more tangible at the moment, detached from whether the cities do have the capability right now to become carbon neutral or not only based on their own efforts (Laine et al., 2020).

Offsetting one's carbon emissions is nowadays widely used and offered in many different ways, from offsetting personal emissions of flights or hotel stays, to trading emissions on a market. How it is applied and what kind of compensation is allowed, strongly depends on the program an organisation might join to make commitments, as well as on the rules outlining voluntary actions or on carbon mitigations required by law. Organisations that award carbon labels for example often require the usage of certified offsetting options, like Verified Emissions Reductions (VER) or UNFCCC certified offsetting projects, if the company plans to use compensation payments to reach carbon neutrality (e.g. carbon-connect AG, 2020; Castro, 2020; CO2-Neutral-label, 2020). This aspect is further explained in a later chapter on certifying carbon neutrality. However, offsetting is not seen by everyone as a good solution for achieving carbon neutrality also in the context of higher education institutions. While the association supporting American universities on their path towards net-zero emissions supports the inclusion of emission offsetting (Second Nature, 2021), the theses on sustainable development published by the Finnish universities for example are seeing it only as absolutely last possibility if there is no other way to achieve carbon neutrality (UNIFI, 2020).

3 LEGISLATIVE AND VOLUNTARY COMMITMENTS FOR CARBON NEUTRALITY

Achieving carbon neutrality is nowadays supported by legally binding policies, as well as voluntary pledges, which create a framework for formulating action plans and further commitments. This chapter will present various decarbonisation goals, from a European and Finnish perspective, but also worldwide commitments and small-scale actions from cities and organisations are described. Furthermore, analysations of the progress towards reaching the main climate goals on different levels are displayed to put the pledges and efforts in perspective.

3.1 Climate and energy policies in Europe

3.1.1 European policies on climate and energy

The climate and energy policies of the European Union are the key legislations in relation to addressing the issue of climate change and aiming towards carbon neutrality. So far, three different policies were adopted: the ‘2020 Climate and Energy Package’, the ‘2030 Climate and Energy Framework’ and the ‘2050 Long-term Strategy’. They are backed up by the ‘Treaty on the Functioning of the European Union’, specifically Articles 191 and 194 that are concerned with the climate and the ongoing global warming, as well as energy-related issues, like increasing efficiency or supporting renewable energy technologies. (Amanatidis, 2019)

The policy for 2020 adopted the so-called ‘20-20-20 goals’: mitigating emissions by 20% compared to the pre-industrial level, raising the share of renewable energies by 20% and ensuring a decline of 20% in the utilisation of primary energy. Those targets were supported by several measures and directives. (Amanatidis, 2019) The creation of the EU’s Emissions Trading System (ETS), for instance, was done in order to support the decrease of emitted emissions in the energy and industry sector. The ETS features a yearly limit on allowances for emissions, a so-called cap, which is decreasing in time, coupling economic concerns with climate-related issues. (Directive on Emissions Reduction (EU) 2018/410, 2018) Furthermore, to ensure the implementation of renewable energy sources in all member states of the EU, every country was assigned a ‘National Renewable Energy Target’ depending on their initial situation and what shares could be realistically expected in upcoming years (Renewable Energy Directive (EU) 2018/2001, 2018). Lastly, a directive concerning CCS was adopted as part of the climate package for 2020 as well, providing a framework for the necessary technologies (CCS Directive 2009/31/EC, 2009).

The policy for 2030 introduced new target values for the same categories as previously adopted for 2020. The share of renewable sources in the energy mix in Europe is supposed to reach at least 32% and the energy efficiency has to rise by 32.5%. (Amanatidis, 2019) The mitigation of GHG emissions by 2030 was eventually decided to account for at least 55% in 2018 (European Parliament, 2020). Moreover, the yearly reduction of emission allowances in the ETS was further increased to ensure a faster decrease of emissions in energy and industry sectors (Directive on Emissions Reduction (EU) 2018/410, 2018). In addition to that, the Directives on Energy Performance in Buildings (Directive on Energy Performance of Buildings (EU) 2018/844, 2018), on Energy Efficiency (Energy Efficiency Directive (EU) 2018/2002, 2018) and for Renewable Energies (Renewable Energy Directive (EU) 2018/2001, 2018) were revised to match the targets for 2030. Additionally, a new rule was adopted in the 'Regulation on land use, land-use change and forestry' (LULUCF) that requires the offsetting of all emissions caused due to deforestation by each member of the EU in form of managing indirect carbon sinks, for example via afforestation (LULUCF Regulation (EU) 2018/841, 2018).

The previously introduced policies are providing the basis for the '2050 Long-term strategy', which is implementing pathways for achieving a net zero balance of emissions featuring all sectors of the European economy. The targets are planned to align with the requirements posed by the Paris Agreement and the Sustainable Development Goals developed by the United Nations (UN). The strategy is now promoted as the new European Green Deal and was also officially submitted to the UNFCCC, the organisation responsible for the Paris Agreement. (Amanatidis, 2019)

According to the European Commission (2016), the utilisation of carbon capture and storage strategies are implemented in the key legislations as well, after the 2020 policy package laid down the basic legal framework. In case it is not possible to reach the mitigation goals with more conventional methods, the usage of CCS will be discussed and adopted for the EU. It is included in the 2030 policy framework and is supposed to especially play a role on the long run towards the end of the set time frame for achieving carbon neutrality. (European Commission, 2016)

3.1.2 European Green Deal

The European Union declared to aim for carbon neutrality by 2050. This goal is featured in the newly proposed European Green Deal and refers to net zero greenhouse gas emissions by all member states of the Union. (European Commission, 2019b) The proposal includes the focus on resources and energy efficiency, as well as the declaration to achieve those goals while at the same time pushing for a competitive economy. But the main aspect is the deep decarbonisation of all aspects of society and covering all sectors in Europe: energy, transport, agriculture, and industry. Emissions that cannot be decreased are supposed to be handled via sequestration options, direct and indirect ones. (European Union, 2019a)

For the industrial sector, the strategies are planning to replace energy sources and raw materials that are responsible for high emission rates with renewable feedstock, such as synthetic gases, hydrogen, or biomass. The electrification of current processes is also proposed as option, alongside a potential modernisation of technological processes aiming for instance towards higher efficiency. The promotion of circular economy methods is another featured strategy. Energy efficiency and the continuing implementation of renewable energy sources remain the key aspects for the energy sector. In the transportation sector, the EU is aiming for establishing smart and sustainable mobility options. This includes for example low-carbon fuels for individual mobility, support for car-sharing strategies and the development of the public transport systems. Another aspect in accordance with reaching carbon neutrality in 2050, is the rehabilitation of indirect carbon sinks like peat- and wetlands as part of the land-use management. Better handling of soil and farmland is another strategy in the agricultural sector corresponding with the European Green Deal. (European Commission, 2019b)

In addition, the EU is planning to include the citizens in the effort towards carbon neutrality with the help of climate pacts that are meant to encourage the active participation in climate actions. A revision for land-use plans, the continuing support for the European Emission Trading System, the introduction of new standards for technologies regarding their emission rates and the demand for national action plans are the key policies that will be utilised for reaching net zero emissions in 2050. (European Commission, 2019a)

In addition to the 2050 objectives, the European Union has also established an intermediate goal for 2030 featured in the climate policies for that year. Initially, it included the reduction of emissions by a minimum of 40%, which was later changed to at least 55% (European Parliament, 2020). Recently, a new intermediate milestone on the way to carbon neutrality was proposed: In 2030, the mitigation level of greenhouse gas emissions is supposed to sum up to 60%, all in reference to the amount of emissions in 1990. (European Parliament, 2019)

Another recent objective of the European Union in relation to the European Green Deal is the plan to adopt a new European Climate Law to transform the commitment proposed by the deal into a legally binding goal. The law proposed by the European Commission is said to be assessed in the course of this year; so far, a preliminary version was agreed upon by European Council and Parliament. In addition to the end goal for 2050, the law is said to feature additional trajectory pathways from 2030 onwards to allow the evaluation of progress over the years and create stability for everyone depending on clearly defined mitigation timelines. (European Commission, 2020)

While the European Union is inducing this overall goal for all members, the individual countries are deciding more separately which pathways for the future they are going to choose. As each country has an individual background with unique characteristics, everyone would need varying strategies to reach the ultimate, European-wide goal of carbon neutrality or at least a strong reduction of greenhouse gas emissions in 2050 (Zlaugotne et al., 2020). A handful of countries have introduced carbon neutrality by 2050 as legislative action, including Denmark, Hungary, France, and Germany. Other states like Sweden are going a bit further, planning for a climate neutral country in 2045. (European Parliament, 2019) However, there are also countries, for example Portugal, where the goal is already formulated but not yet made into a law (Gil & Bernardo, 2020).

3.1.3 National climate policies in Finland

Finland is one of the forerunners in terms of goals for reaching carbon neutrality, as the nation is aiming for it already by 2035 (Valtioneuvosto, 2020). Considering the fact that the country is one of Europe's biggest emitters of carbon emissions per capita (Pilpola et al., 2019) this has the potential to act as a strong statement with signalling effect. The high amount of emissions is especially related to the energy-sector, reflecting an increased demand for energy due to cold climate and an energy-intensive industry (Ministry of the Environment & Statistics Finland, 2017). From the Finnish government's point of view, carbon neutrality is equal to reducing emissions by around 90 to 95% compared to 1990 (Pilpola et al., 2019; TEM, 2020). The approach the country is taking features the strengthening of renewable energy sources, the phase-out of coal from energy production in 2029, but also decreasing the carbon footprint for construction, housing and along the food chain. Fossil fuels are supposed to be banned completely and by improving the management of natural carbon sinks, the country hopes to even achieve a carbon negative net emissions balance after 2035, meaning to even remove emissions from the atmosphere. (Valtioneuvosto, 2020) The Finnish government analysed that the amount of carbon emissions to be mitigated in Finland adds up to almost 35 Mt of CO_2e (Finnish Government, 2020), indicating a long way to go for reaching a net zero balance. The mitigation of emissions is supposed to be followed for all sectors: non-emission trading sectors and the sectors that are part of the European Trading Scheme. (TEM, 2019)

The most recent Finnish National Energy and Climate Plan (NECP) which was submitted as 'Integrated Energy and Climate Plan' in 2019 by Finland to the European Union, lays out the majority of these proposals (TEM, 2019). But due to the new goal of reaching carbon neutrality already in 2035, as announced in 2020, the scope and timeline for the proposed strategies is not suitable anymore. The current NECP is based upon the preposition to reach carbon neutrality in 2045 utilising data analysed in 2016/17. (TEM, 2019). The revised goal is, however, featured already in a strategy paper handed in to the European Commission in spring 2020. It includes scenarios on how Finland plans to achieve the goal of reaching carbon neutrality by 2035 and what amounts of saved emissions could be achieved based on different pathways, depending on various technologies, the possible application of CCS technologies and the solutions for managing the indirect carbon sinks of the country. (TEM, 2020)

The 'Climate Change Act' is the key legislation in Finland for the nation's policies on climate and energy. Based on the fact that it was adopted in 2015, it does not endorse the more recent carbon neutrality goal yet, similar to the NECP submitted to the European Union. Due the more ambitious target year for achieving net zero emissions, Prime Minister Sanna Marin's Government scheduled the revision of the current 'Medium-term

Climate Change Policy Plan', a revised 'Climate and Energy Strategy' and an amended Climate Programme for the land use sector during the ongoing year, as well as the improvement of the 'Climate Change Act' itself. (YM, 2021) The listed strategies are the system of policies that support the planning for climate actions in Finland. Not yet fully developed is the 'Long-term Climate Change Policy Plan', but it is going to be another component of the policy system. In addition to the legislative framework, there are also yearly reports on climate change published, analysing the progress the country has made in terms of mitigating GHG emissions and staying on track with the proposed carbon neutrality goals. (YM, 2021)

3.2 Pledges and goals for decarbonisation

The alarming state of the global warming process requires the world to take action immediately. In relation to this urgency, the shift towards emitting less greenhouse gas emissions is nowadays anchored in various international treaties, national action plans, as well as pledges made by individual companies or organisations. In contrast to the previously presented legislations in Europe these pledges are often on a voluntary level or not fully legally-binding and therefore do not invite the same strictness as could be achieved with laws.

3.2.1 Paris Agreement

One of the most well-known treaties is probably the Paris Agreement, worked out and signed in 2015 during the 21. Conference of the Parties (COP) hosted by the United Nations Framework Convention on Climate Change (UNFCCC). It can be counted as one of the recent major achievements for combatting climate change on an international scale in tradition of popular treaties such as the Kyoto Protocol from 1997. The overall vision the treaty is aiming for is to keep the effect of the global warming under 2°C or even as low as 1.5°C on the long run, by drastically reducing greenhouse gas emissions. The reference time period is the level found before the industrialisation. The initiative was signed by the participating parties of the COP in Paris and finally adopted in 2016. (UNFCCC, 2021b) To this date, the agreement serves as one of the most cited reasons when countries, organisations, or companies commit themselves towards decarbonisation, as the treaty and subsequently published reports on the consequences of climate change (e.g. the regularly published IPCC reports, like "Global Warming of 1.5°C" (IPCC, 2018)) keep on supporting the necessity of acting as fast as possible. The

European legislations, for instance, are partially adopted to fit the requirements introduced by the Paris Agreement, as well as additional declarations from subsequent COPs (Amanatidis, 2019).

The Paris Agreement is an international treaty recognised by international law, but besides its widely acknowledged importance not every part of the agreement is legally binding for the signatories. In fact, the commitments for mitigating greenhouse gas emissions as well as pledges for certain financial acts are only promises and carry no legal repercussion if not followed. Only the reporting of emission inventories and the manufacturing of national action plans (so-called nationally determined contributions - NDCs) is more or less mandatory from a legal point of view. However, following those NDCs and achieving the planned steps is again not linked to penalties by failure. (C2ES, 2020) Only if the signatories are adopting the commitments posed by the treaty into their national legislation framework is the Paris Agreement background for completely legally binding action.

3.2.2 Sustainable Development Goals

In addition to the Paris Agreement, the United Nations are involved in another relevant set of goals in relation to carbon neutrality: the 2030 Agenda for Sustainable Development. The targets adopted by the member states of the UN are not focussing solely on climate change issues but recognise the interconnected dependency of sustainable goals, such as ending poverty, providing education or protecting the natural ecosystem (United Nations, 2018), and therefore making them relevant for aiming towards carbon neutrality as well. The European Union (2019b) lists a number of sustainable development goals (SDGs) that are in close relation to the decarbonisation goals as targets to be aimed for. At least 7 of the 17 goals would either benefit from a low carbon economy or would influence the possibility to build such a society in Europe. In addition to the more obvious goals such as effort in climate action (#13) or increasing the use of clean energy (#7), the nature orientated goals for protection of flora and fauna (#14 and #15) would also benefit from a deep decarbonisation in the European Union, as well as worldwide. The European Green Deal presented earlier, is partially an answer to the SDGs next to the influence of the Paris Agreement.

3.2.3 Local action plans – commitments from cities

Not only on an international level are climate related goals established, many cities from around the world are aiming for carbon neutrality in their own context and within their system boundaries. Sometimes the goals are even defined independently from national strategies and pathways, favouring stricter and faster carbonisation targets. Examples for such proactive decisions in the Nordic countries are the cities Copenhagen, Oslo and Stockholm (Dahal & Niemelä, 2016), as well as many of the bigger cities in Finland (Laine et al., 2020).

In addition to individual actions, there are already several initiatives worldwide that group cities together and provide a platform to share experience, announce the commitments, as well as to offer help in achieving the goals. Examples are the so-called 'C40' network (Laine et al., 2020), the 'Climate Alliance' (Salvia et al., 2021), the 'Carbon Neutral Cities Alliance' (Tozer & Klenk, 2018) or the Finnish 'Hinku' network for municipalities (SYKE, 2021). The initiatives are aiming for cities with zero net emissions with the help of offsetting measures or even without those compensation payments. In their analysis of several hundred local action plans, Salvia et al. (2021) revealed that on average European cities have set 2045 as their final year for reaching carbon neutrality, if the plan features a target for total emission reduction - which only a quarter of the analysed action plans had. Others simply include mitigation goals, adding up to an average decrease of emissions by just about 47%. The analysis additionally stated that the action plans differ greatly from each other, especially in terms of aimed for mitigation goal, baseline year and target year. Carbon neutrality is either mentioned with concrete deadlines and action plans leading towards the goal or just as a statement, where the cities' stakeholders simply announce their intention to reach carbon neutrality at a not further specified point in the future. (Salvia et al., 2021)

Despite the relatively low goal on average, quite a number of cities are featuring more drastic aims than their respective national governments (Laine et al., 2020), as already mentioned above. In Europe, the majority of the highly ambitious cities can be found in the Northern and Western areas and the commitment also depends on the size and population, as well as whether a membership in one of the many climate alliance does exist (Salvia et al., 2021). However, in relation to such ambitions, Laine et al. (2020) raised the question how realistic such an endeavour could proof to be if the focus is on true mitigation and not simply in combination with offsetting the main part of emissions, based on the fact that cities are not separated entities and embedded in the proceedings of their national government. Their analysis of action plans implemented by cities, especially in Finland, resulted in the statement that the true impact on the way towards carbon neutrality will be achieved on a national level or in collaboration with international stakeholders and not solely from individual municipalities or local action plans. One reason for that was also found in allocation issues and the question of who is really responsible for what part of the emissions. However, on the big picture the local action plans are found to be helpful by supporting the bigger strategies – and necessary, because national or international plans might be too vague to lead to concrete actions on a very small scale (Laine et al., 2020).

Many of the initiatives for carbon neutral cities have an undeniable focus on energy-related carbon emissions as the results of the analyses done by Laine et al. (2020) and Salvia et al. (2021) are showing. The energy sector is a favoured place to start with the decarbonisation of cities, as the emissions due to energy generation for heating, transportation or electricity have been found to often account for the vast majority of emissions in cities. This is for example supported by the research of Dahal & Niemelä (2016), who assumed in their analysis of the Helsinki metropolitan area that only 4% of all emissions are not energy-based inside the chosen system boundary, marking their high importance in relation to appropriate climate action plans. But, as stated by Gil & Bernardo (2020), the true carbon neutrality can only be reached in the end when all sectors and areas of economy and society work together, combining individual measurements to a potential, climate neutral future. Industry, energy generation, land use and the management of transport systems and infrastructure in rural and urban areas need to be transformed quickly with the focus on low-carbon technologies and sustainable development to keep the limits set by the Paris Agreement (IPCC, 2018).

3.2.4 Commitments on a smaller scale – the case of companies and institutions

Large scale commitments have been made on international and national level, but in addition to countries and cities, there are also companies that made a pledge to reach carbon neutrality. An agreement that is lately growing in signatories is 'The Climate Pledge' founded by Amazon. It includes well-known companies like Microsoft, Unilever, Mercedes-Benz and Siemens, who are all aiming for net zero GHG emissions by 2040 – 10 years earlier than suggested by the Paris Agreement. (Holbrook, 2020) Other initiatives include for example the UN-supported network 'Climate Neutral Now Pledge', which strives to support companies and organisation by measuring their emissions, mitigating them as far as possible and lastly offsetting the remaining amounts (UNFCCC, 2021a).

Another category of organisations joining climate initiatives are, among others, institutions for higher education. As early as 2006, the American College & University Presidents' Climate Commitment was initiated and adopted by over 700 institutions in its early years. The signatories agreed to analyse their emissions, find possibilities of reducing them in terms of action plans and report on a regular basis to the committee of the commitment. (United Nations, 2013) Nowadays the commitment doesn't exist anymore in its original form but is integrated in the network of the non-profit organisation Second Nature who is coordinating projects like the 'University Climate Change Coalition', the 'Climate Leadership Network' and the 'Offset Network'. Educational institutions in America can sign various pledges and become part of the network with the overall goal of mitigating emissions. (Second Nature, 2018) A handful of participating colleges and universities even consider themselves already to be carbon neutral, for example the University of San Francisco since 2019 or the Colby College in Maine since 2013 (Second Nature, 2020) – mainly in combination with offsetting measures.

In a somewhat similar approach, a working group consisting of several Finnish universities released a statement in 2020 featuring a collection of theses meant to inspire and guide institutions of higher education in Finland to make binding commitments for sustainable development. Those include the goal to achieve carbon neutrality in 2030, so as to stay in line with the programme of the Finnish government depicting the pathway towards the whole country's net zero emissions balance five years after that. (UNIFI, 2020)

3.2.5 Collaboration in relation to commitments

In regard to the different natures of all the mentioned pledges, working together is one of the keys to managing the whole situation, starting by international commitments over national implementation of those goals to local actions by municipalities, organisations, companies, or educational institutions. Only if everyone works together, like cogwheels as part of a whole machinery, can the climate neutrality be achieved. An example for that is provided by the research of Dahal & Niemelä (2016) on the efforts undertaken in the Helsinki metropolitan area in relation to carbon neutrality. They stated that a missing commitment by the cities in the investigated area might lead to the fact that the overall goal will not be reached if it was not for the progress shown by big companies with carbon neutrality goals, such as the energy company Helen Oy. Individual goals on a smaller scale will in the end support the net zero emissions target for the whole region or a country.

Furthermore, the usefulness of networks where like-minded institutions are able to connect with and support each other was pointed out by Tozer & Klenk (2018). Their analysis of urban action plans came to the conclusion that sharing thoughts about mitigation measures and approaches has a very positive effect on the individual performance of a network's or alliance's member, especially in the context of the trial-and-error approach political and economic decisions are often shaped out to be as there is no perfect blueprint yet for achieving carbon neutrality.

3.3 Tracking the progress towards carbon neutrality

Integrating goals in legislative actions of national governments, city committees or leading panels of organisations is considered to be the first step in the commitment to fight climate change. Detailed milestones can from the perspective of long-term strategies be considered as beneficial in determining whether the object of investigation is on track to reaching the implemented carbon neutrality goals and clear numbers of mitigation rates are useful for evaluating the progress. Detailed pathways with descriptions on how the reduction of greenhouse gas emissions will be achieved are advantageous as well. In relation to those, models can be created to evaluate the effort and compare the efforts and goals of competitors or between different countries. Such analyses are provided in various research papers, by the organisations responsible for certain treaties or by independent third parties and will be presented in the following.

3.3.1 Progress of national and international commitments

Corresponding to the United Nations, over 110 countries have so far announced or planned a commitment for carbon neutrality with the majority pledging it for 2050. Despite this fact, the UN's secretary-general Antonio Guterres criticised in a recent video message that the countries should adopt more concrete policies in spirit of their formulated goals, which is currently not done in an adequate way, and adjust them to cater to the need of keeping the global warming at 1.5°C, not only at 2°C. Another voiced criticism is the lacking financial commitment shown by many countries. (United Nations, 2020a) This paints a more negative than positive outlook of the international community's performance.

According to the EU's own perspective, the progress the Union has made so far is a largely positive one and Europe can be seen as one of the economic areas with the most efficient management of carbon emissions worldwide. In addition, it claims to have achieved a decoupling of GDP growth and GHG emission rates by following a transition pathway featuring low-carbon technologies. (European Union, 2019b) However, one recent creditable step was the announcement of the new intermediate milestone of 60% emissions mitigation by 2030 (European Parliament, 2019), instead of only 40% as originally planned (TEM, 2017).

Other analyses draw a more critical picture of the European progress in terms of carbon neutrality. The Climate Action Tracker for example rates the effort of the EU as insufficient. Their analysis of the historic development and the potential long-term pathways showed that the EU is not on track to keep the Paris Agreement's limit of 1.5°C. If only today's action would remain, the global warming would not stop before 3°C. One of the main criticisms was the lacking midterm goal for 2030. The analysists assume that the new development for that part could lead to a slightly better result for the European progress. In the end, the Climate Action Tracker summarises the implemented efforts of the member states as only leading so far to a mitigation of 37% compared to 1990. Even when counting the new initiative by the European Union, only a reduction of 48% in 2030 seems likely at the moment. (Climate Analytics & NewClimate Institute, 2020a) On a worldwide perspective, a more positive signal was given at the end of 2020. The actions taken so far are presumed to be now in line with a global warming of maybe only 2.1°C at the end of the century, but only if the optimistic assumptions and proposed trends are being kept. Previously the prediction was set to 2.6°C. (Climate Analytics & NewClimate Institute, 2020b)

Figure 2 depicts the individual evaluation by the Climate Action Tracker of several countries around the world in accordance with the goals of the Paris Agreement. As can be seen, the majority of the assessed countries are taking insufficient actions and only six countries were deemed to have implemented regulations that are compatible with the limit set for global warming.

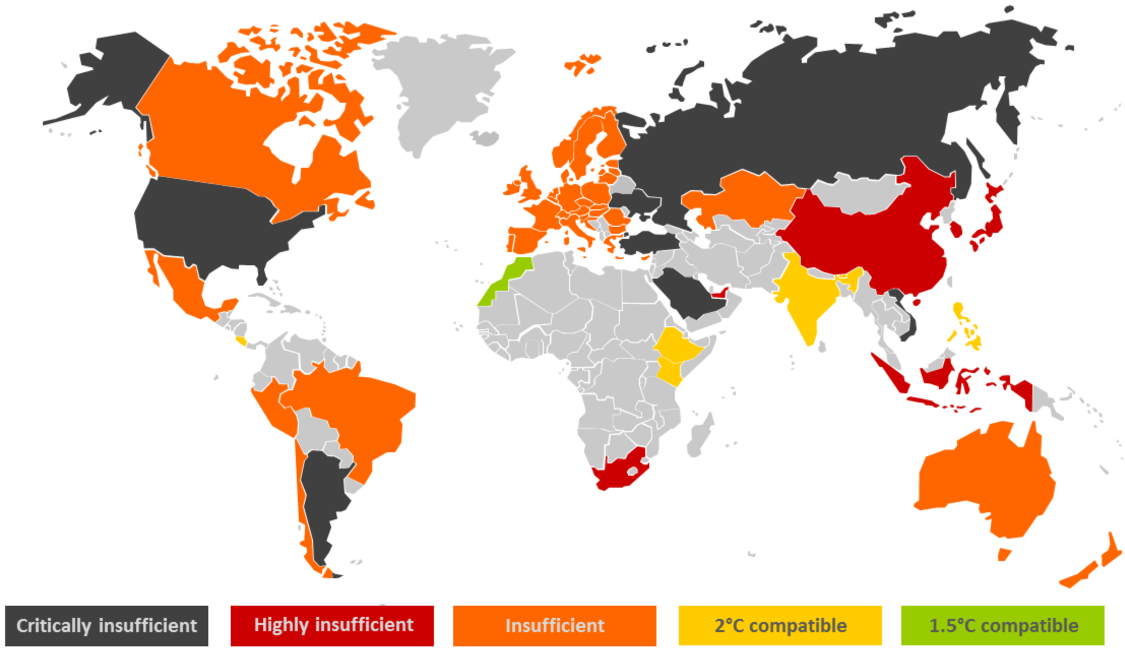

Figure 2. Evaluation of worldwide efforts in relation to the Paris Agreement as at November 2020 (retell Climate Analytics & NewClimate Institute, 2020c).

Analysing the effort towards decarbonisation a few years ago, Spencer et al. (2017) found that there was definitely a progress visible for the member states of the EU. However, it was already concluded at that point that an increase of action would be needed. By comparing the decarbonisation rate for different time frames starting in the early 2000s, the authors came to the conclusion that if the trend of the last years would simply be continued the benchmarks defined in the national decarbonisation goals would be missed in the upcoming years. They stated the need for a much stronger declining rate of the carbon emissions factor necessary to stay on track with the aims for example presented in the Paris Agreement. Looking at the rate of carbon intensity, today's efforts will especially fall short in the energy sector, the residential building sector, and the transport sector. Only the industry sector seems to be broadly in line with the benchmarks set for the upcoming decades. (Spencer et al., 2017) A similar conclusion was achieved by an analysation of performances in context of GHG emissions mitigation by Zlaugotne et al. (2020), who declared the current concrete efforts agreed on by the European Union by far not enough to achieve the desired mitigation. Only around 60% of the necessary emissions reduction are so far accounted for with either plans or detailed actions, leaving a lot of room for more progress and improvement.

3.3.2 Progress of small-scale commitments

On a smaller scale, a large portion of European cities are still not committed enough towards carbon neutrality to stay on track with the global warming limit favoured by the Paris Agreement. According to Salvia et al. (2021) the effort up until now does not even equal half of the ambitions that would be necessary. Apart from falling short of even naming goals that are in line with the overall mitigation target another problem is that it is not clear whether already taken approaches and measures are likely to lead to the desired outcome even when carbon neutrality is taken on as end goal. Dahal & Niemelä (2016), for example, already acknowledged a couple of years ago the hard challenges a city like Helsinki will have to face when it is aiming to contribute to a national goal of net zero GHG emissions in 2050.

Already several years ago, Barker & Crawford-Brown (2015, pp. 347–351) highlighted in their analysis of climate policies the urgency required in contrast to the relatively weak progress of a debate that was ongoing for already a couple of decades. The later the change towards a carbon neutral society is achieved, the more unforgiving the consequences of the climate change will be. In addition, it is also stated that the costs will be higher in the future if the necessary transition happens too late, supporting the notion that the most advantageous line of action would be to start now in a serious and proactive way towards carbon neutrality. Even the United Nations officially acknowledged the fact that the commitments pledged around the world are not yet enough to slow down or stop the global warming (UNEP, 2019).

4 CARBON FOOTPRINT – A TOOL OF CARBON NEUTRALITY

In the context of ongoing climate change and the call to make an effort to slow down global warming, mitigating emissions is one of the top priorities. When considering the goal to reach carbon neutrality or to reduce specific emission rates, it is first important to know how much emissions are generated by whom, or what part of a process or activity has the highest share of emissions. One kind of greenhouse gas inventory is represented by the carbon footprint, a tool that is quite popular nowadays. In the following, the concept behind the carbon footprint will be explored and the major calculation methodologies proposed by related standards and guidelines presented. In addition, the connection between the carbon footprint, offsetting emissions and the certification of carbon neutrality will be explored.

4.1 What is the carbon footprint?

4.1.1 Definition of carbon footprint

The carbon footprint is a form of emissions accounting or inventory record (Pandey et al., 2011) where all emissions caused by and related to a certain product or the activities of an organisation are assessed and accounted for (Wiedmann & Minx, 2007). This includes emissions directly caused by the investigated system, as well as certain indirectly emitted emissions depending on the chosen system boundaries (Wiedmann & Minx, 2007). For instance for products, it is often that all stages of the life cycle are considered for the calculation (Gao et al., 2014). The completeness of measuring the released emissions is a key principle for all possible objects of investigation, with the goal to show the total quantity of emissions. The prevailing unit in which the carbon footprint is presented is a mass unit. (Harangozo & Szigeti, 2017) The aforementioned activities can include all kinds of events and actions (e.g. sport events or natural disasters like forest fires), as well as processes of corporations or organisations (e.g. businesses, governmental or educational institutions) and even cities or whole countries can be assessed. In general, a carbon footprint can be compiled for almost everything if the required information and data can be found. (Pandey et al., 2011)

4.1.2 Scopes of emissions

One of the early topics of discussion revolved around the question what kind of emissions should be assessed in a carbon footprint, especially how to differentiate between various direct and indirect emissions (Wiedmann & Minx, 2007). As an answer to that, many tools and guidelines are nowadays using the GHG Protocol Standard's emissions scope definition as guideline, which includes three tiers for defining the various kinds of emissions and was published by the World Resources Institute and the World Business Council for Sustainable Development. The first tier refers strictly to the direct emissions caused directly by the product or the investigated activity, e.g. due to the onsite burning of fossil fuels, whereas second and third tier represent the indirect emissions. The distinguishment between those two tiers refers mainly to the fact that for the second one only energy-related indirect emissions are considered, meaning that all emissions, which were caused during the generation of the purchased energy used by a product or during an activity, are counted. All other indirect emissions are collected in tier 3, including for example emissions caused by business travels or commuting and ones caused by waste disposal. (WRI & WBCSD, 2004)

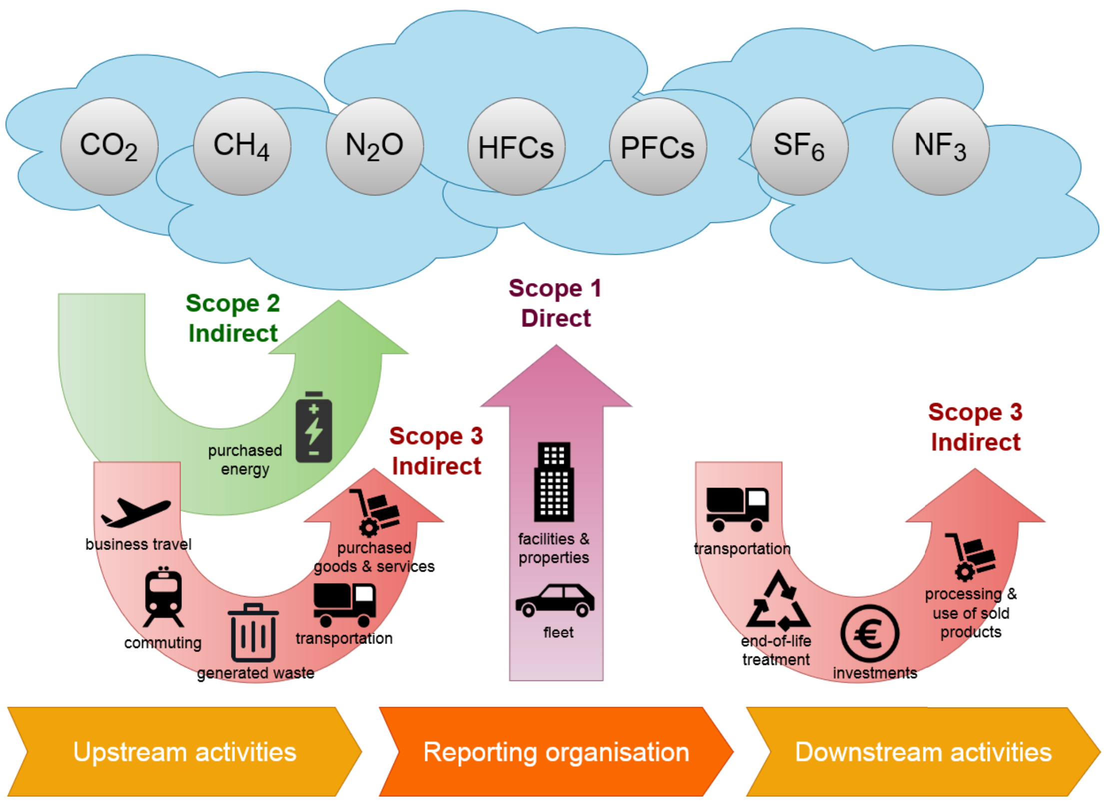

Figure 3. Scopes of emissions (retell WRI & WBCSD, 2013).

Another term for the indirect emissions is ‘embodied emissions’, referring to the fact that these emissions are not directly generated by the product or activity investigated, but where emitted either by necessary ancillary actions (like the generation of needed electricity) or down- and upstream of an evaluated process (e.g. transportation or mining of needed raw materials). In essence, every emission that occurred in relation to the analysed objective, but is outside of the direct boundaries that define the direct emissions is called an indirect emission. (Pandey et al., 2011) Figure 3 depicts the defined scopes of emissions with examples following the value chain of a company or organisation as used by the GHG Protocol Standards.

4.1.3 Historical development of the footprint approach

Although the carbon footprint gained its popularity mainly during the last decade, its origins can be traced back to the end of the last century. Especially in terms of the name, there is a relationship to the early considerations about so-called ecological footprints as for example presented by Wackernagel & Rees in 1996. Their definition of ecological impact was closely related to an actual area of land, symbolising what space would be needed to sequestrate the caused emissions, hence the term ‘footprint’. (Pandey et al., 2011) The name remained but the meaning changed compared to the original approach, with the carbon footprint now not reported as area but in form of a mass unit (Pandey et al., 2011).

While earlier researches on the footprinting concept, for instance done by Wiedmann & Minx (2007), still advocated for the separation of carbon and other greenhouse gas emissions when defining and calculating the carbon footprint, it is nowadays the prevalent practice to take all GHG emissions into consideration, with the relevant gases often defined by the Kyoto Agreement (Harangozo & Szigeti, 2017) or the IPCC (ISO, 2018a). The presentation of the carbon footprint is therefore often done in the mass unit of tonnes of CO_2 equivalents, in accordance with the specific global warming potential (GWP) of the included gases (Pandey et al., 2011). This is on par with the commonly applied definition for carbon neutrality, as presented in the previous chapters, ensuring a consistent terminology between the process and goal, as well as the utilised tools.

4.1.4 Motivation for calculating a carbon footprint

The main motivation behind a carbon footprint often depends on whom the final information is addressed to. A carbon footprint or greenhouse gas emission inventory can be either required by law or done in a voluntary fashion and might be aimed at the customers of certain products or will be utilised directly by a company in relation to emission trading programs or emission caps (Pandey et al., 2011). Despite different backgrounds to why a carbon footprint is calculated, the main reason is often to establish how climate-friendly a product or activity is and possibly even to sensitise or raise awareness towards the impacts certain actions have on the planet in form of GHG emissions (Weidema et al., 2008).

Notwithstanding the different incentives to conduct the calculation of a carbon footprint, the end result will help with identifying the major sources of emissions, which can be used as starting point for planning effective mitigation measures for greenhouse gas emissions (Awanthi & Navaratne, 2018) or to figure out the amount of required offsetting measures (Pandey et al., 2011). In addition, it can be used to track the performance's progress and therefore help drawing up climate-related goals and action plans (Awanthi & Navaratne, 2018). Both aspects mark the carbon footprint as an important tool on the pathway towards carbon neutrality.

4.1.5 Relevant standards and guidelines for calculating carbon footprints

The carbon footprint (especially the one for products) is sometimes also seen as a limited version of a Life-Cycle Assessment (LCA). In their analysis of this topic, Weidema et al. (2008) claimed that compared to a complex LCA study people can easier grasp the meaning of a carbon footprint, as it focuses solely on one indicator instead of featuring many different impact categories. In terms of indicators, the footprint resembles most closely the global warming potential indicator that is often utilised in LCAs and is also inspired by it (Finkbeiner, 2009).

The definition of the term alone does not strictly clarify the means by which the carbon footprint has to be calculated. Especially at the early stages, there were many different approaches being used under the same term, or at least similar names, by various private companies or institutions (Pandey et al., 2011). At some point, the need for more standardised methodologies was recognised and several initiatives started to develop commonly useable approaches. Based on that there are various guidelines that can be followed when establishing a footprint. The most widely used standards are the GHG Protocol Standard worked out by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WCSD), as well as the Publicly Available Specification (PAS) guidelines published by the British Standards Institution (BSI) (Gao et al., 2014). The following chapter will address their methodologies in more detail.

4.2 Methodologies and guidelines

As the carbon footprint concept has now been already used for several years, there are various ways available by now to conduct the calculations. In earlier years, there was no clearly specified approach and widely recognised guidelines were missing. One of the first methodologies specifically focusing on establishing a carbon footprint was published by the WCSD and the WRI under the name of 'The Greenhouse Gas Protocol'. The first version of the guideline was introduced already in 1998 (Liu et al., 2016). Until today, the suggested rules and methods are often the basis or starting point for more recently developed standards and calculation tools (Harangozo & Szigeti, 2017). In addition to the more internationally orientated initiatives, there were also national advances early on for creating more specific, localised guidelines, for example in Japan and Korea, as well as in Germany and New Zealand, most of them seeing the carbon footprint simply as some version of an LCA-process (Finkbeiner, 2009).

In general, there are two different main approaches for the calculation methods depending on the object of investigation. The first group of approaches consists of guidelines for product-based calculations; and often those are the ones primarily resembling an LCA process, as it is an advantageous methodology on a smaller scale (Gao et al., 2014). The other group focusses on the calculation efforts needed to assess the footprint of organisations, institutions, or companies; with an approach that is more inspired by an input-output analysis (Gao et al., 2014). While the characteristics of the results are quite similar - the footprint is reported for both groups in a mass unit - the individual methodologies vary slightly to account for the diverse nature of the analysed subjects. In addition, the different carbon footprints can be categorised by the fact which tiers of emissions (see GHG protocol definition as presented by WRI & WBCSD, 2004 and outlined above) are included in the calculation. Primary or basic footprints only consider tier 1 and tier 2 emissions, which are the absolute minimum requirements. More fully analysed assessments also feature certain tier 3 emissions. But while the last option might provide a wider range of impacts and is often considered to include the largest share of emissions, this approach is much less straightforward to assess and can therefore lead to complications and errors. (Pandey et al., 2011)

As the establishment of methods for a carbon neutral campus is the main objective this work is supporting, the focus for presenting the different guidelines will be on the carbon footprint methodologies for the organisational level. However, as the footprint for products is not less important, it will also be described in the following.

4.2.1 Background methodologies

The major guidelines for carbon footprinting are mostly based on other commonly used assessment methodologies as pointed out above. To provide a better understanding of the underlaying basic structures for calculating the carbon footprint, the two most popular background methodologies, Life-Cycle Assessment (LCA) and Input-Output Analysis (IOA), will be explained in the following. Those methods are analysis tools in their own right but are typically not used in their basic form to directly conduct a carbon footprint calculation, merely providing the basis for the guidelines presented later on.

4.2.1.1 Life-Cycle Assessment

The Life-Cycle Assessment is a method for analysing product systems regarding their environmental impact. Usually the whole lifetime of a product is taken into consideration, starting with the acquisition of raw material needed for the production of the product and ending with the disposal after its usage. (ISO, 2006) This approach is called 'cradle to grave'. The procedure is standardised by the International Standard Organisation (ISO) and the methodology is mainly outlined by ISO 14040[1] and ISO 14044[2]. (Klöpffer & Grahl, 2014, p. 1)

During an LCA the focus is on ecological factors instead of questioning the economic feasibility or social status of the product. All inputs and outputs of the defined product

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[1] ISO 14040:2006 - Environmental Management. Life Cycle Assessment. Principles and Framework.
[2] ISO 14044:2006 - Environmental Management. Life Cycle Assessment. Requirements and Guidelines.

system are quantified and evaluated, and the discovered potential environmental impacts are eventually analysed and interpreted. (ISO, 2006) The aim is to raise the awareness regarding the environmental performance of a certain product, especially whether there are negative impacts involved and in what order of magnitude. By informing about environmental challenges in the product system, a life-cycle assessment can help to improve the product development in the future or can be used for marketing strategies. Moreover, a circumspectly conducted assessment enables the comparison of products and services focusing on their effects on the environment. The analysis also has the target to choose appropriate indicators at which the performance of the product can be evaluated. (Klöpffer & Grahl, 2014)

The methodology for conducting a Life-Cycle Assessment consists of four major parts. The first phase is concerned with determining the goal of the study and to define the scope. This includes setting up the boundaries of the investigated product system and creating a flow chart of all the processes that will be assessed during the study. Allocation issues are scrutinised during this phase as well, to ensure a consistent representation of the product's impacts. In addition, a so-called 'functional unit' is defined, depicting the purpose of the product system. The functional unit is used to quantify all inputs and outputs necessary for the product system and provides the option of comparing the performances of various product systems with the same function. (ISO, 2006)

After the background for the LCA study is defined, the 'life-cycle inventory analysis' is conducted. All relevant input and output information is assembled during this phase in such a way that they fit the defined scope of the product system and are in line with the functional unit. (ISO, 2006) The collected data includes for instance information acquired from databases or direct measurements, always aiming for data of high quality (Klöpffer & Grahl, 2014).

After conducting the life-cycle inventory analysis, the 'life-cycle impact assessment' is the next step for an LCA. Based on the functional unit of the product system and the results of the inventory analysis, the environmental impacts caused by inputs and outputs are aggregated. The procedure is supposed to help evaluating the scope and relevance of the different environmental burdens caused during the whole life cycle of a product. The impact assessment starts with searching for and deciding on the impact categories and their indicators. (ISO, 2006) Those could for example be 'acidification', indicated in acidification potential based on kg SO_2-equivalents , or the category ‘climate change’ with the unit of kg CO_2-equivalents as indicator for the global warming potential (Klöpffer & Grahl, 2014, p. 236 and p. 256). The next step is the classification of the inventory results, meaning that all inputs and outputs are assigned to the chosen impact categories. Finally, the results for the category indicators are calculated. This step is also called characterisation. (ISO, 2006) In addition to the main tasks, the LCA study provides the possibility to assess the impacts further. The results can for example be normalised, meaning that they are put in relation to appropriate reference information. That way, the results are embedded in a context. Afterwards, grouping and weighing steps can follow. These procedures are used for sorting and ranking the results to provide a more in-depth assessment. (Klöpffer & Grahl, 2014)

The results from the impact assessment are utilised and discussed as part of the interpretation phase. The aim of this step is to provide a conclusion based on the acquired results and present recommendations in relation to the usage of the analysed product system. In addition, the final outputs of the study are checked for completeness and whether the utilised information and applied methodologies were chosen in a consistent way. (ISO, 2006)

As outlined by the International Standardisation Organisation’s (ISO) standards, the last part of an LCA study is the preparation of a report. All aspects of the conducted analysis need to be presented and every step of the procedure will have to be laid out in detail to allow an understanding and critical review of the results. The latter is especially important when the life-cycle assessment is officially published as part of a compulsory assessment of environmental impacts. (ISO, 2006)

4.2.1.2 Input-Output Analysis

The input-output analysis is a top-down methodology to assess economic flows on larger scales (Wiedmann & Minx, 2007) and often applied to national economies (Finnveden et al., 2009). In its origin, the method analyses flows between different economic sectors based on consumed and supplied goods, as well as monetary transactions. The intention is to use the determination of inputs and outputs to gain knowledge about the connections and interactions between the analysed sectors. (Finnveden et al., 2009) The IOA is based on the assumption that the flows are homogenous inside the individual sectors of the overall assessed economic system, therefore putting the focus on relations of a higher level, meaning primarily between the sectors (Wiedmann & Minx, 2007).

The basic approach of an IOA was established by Leontief in the second half of the 20th century but has been continuously developed since then. The starting points for the accounting methodology are matrices, coefficients and tables depicting the inputs and outputs in relation to another. The input-output matrix forms the basis for the calculation of the balances of materials and monetary flows. (Raa, 1994) The balances are basically the relationships between the different analysed sectors. The equations that are used during the standard methodology apply a linear connection. (Leontief, 1986, pp. 19–30)

The main result from conducting an IOA are the input-output tables, depicting the transactions between the sectors (Raa, 1994). They basically consist of a column with the sectors that are selling a certain commodity to another sector, listed in the head-row. The quantities that are exchanged between the individual sectors are defined in the rows and columns of the table, including the total sums of them. Initially, the amounts can be depicted in physical units, but preferably the monetary values or technical coefficients are used. (Leontief, 1986, pp. 19–30) The basic outline of such an input-output table can be seen in Figure 4.

Output to *Input from*	*Sector 1*	*Sector 2*	*Sector 3*	*Total output*
Sector 1	a_{11}	a_{12}	a_{13}	$a_{11}+a_{12}+a_{13}$
Sector 2	a_{21}	a_{22}	a_{23}	$a_{21}+a_{22}+a_{23}$
Sector 3	a_{31}	a_{32}	a_{33}	$a_{31}+a_{32}+a_{33}$
Total input	$a_{11}+a_{21}+a_{31}$	$a_{12}+a_{22}+a_{32}$	$a_{13}+a_{23}+a_{33}$	

Figure 4. Example for an input-output table according to Leontief's concept (based on Leontief, 1986 and Raa, 1994).

Derived from the purely economic-based field of application, it is possible to assign the method of the IOA to other subjects. One of those options is the environmentally extended input-output analysis (EEIOA), where the monetary activities are used as basis to determine the GHG emissions caused by the flows. This way the indirect emissions caused by trading goods and services are accounted for, enabling the assessment of networks on higher levels rather than only product systems as achieved with LCAs. (Caro, 2019) The boundaries limiting the accounting of a system can be drawn as wide as the whole economy when this methodology is used (Wiedmann & Minx, 2007). Based on the analysis of inputs and outputs the methodology enables the assessment of impacts on the environment in accordance with the final consumption of commodities (Wiedmann et al., 2006), connecting for example emission data from direct as well as indirect activities with financial flows and therefore eventually the final consumption (Minx et al., 2009). Because of those characteristics the EEIOA is a commonly applied basic structure for the carbon footprint of organisations or companies (Gao et al., 2014).

4.2.2 Carbon footprint for products

In this category, the main guidelines include the GHG Protocol Product Standard[3], the BSI-issued PAS 2050[4] and the standard ISO 14067[5]. As already mentioned before, this approach of conducting an analysis along the whole life-cycle of a product is strongly based on the process of performing a life-cycle assessment as specified in the earliest versions of standards ISO 14040 and ISO 14044 (Pandey et al., 2011), especially in consideration of the impact category 'global warming potential' or 'climate change', which is the featured analysis of GHG emissions in the LCA's procedure (Klöpffer & Grahl, 2014, pp. 234–239).

One of the aspects that all three major guidelines have in common is the step-by-step outline of the calculation process, adopted from the LCA approach. First of all, there is the analysis of the investigated product's life cycle. When all the stages are determined, a system boundary and a functional unit is defined to provide a clear outline of which stages and therefore what kind of emissions will be included in the analysis. Next up is the actual calculation of the carbon footprint, followed by assembling the results, and reporting or using them in a suitable manner. Popular calculation methods are for example based on databases with actual measurements or rely on weighting emission factors (Gao et al., 2014) These factors are specific, absolute amounts of emissions measured for certain activities enabling the possibility to calculate the GHG emissions of an activity

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[3] Greenhouse Gas Protocol - Product Life Cycle Accounting and Reporting Standard. (2011)
[4] PAS 2050:2011 - Specification for the assessment of the life cycle greenhouse gas emissions of goods and services.
[5] ISO 14067:2018 - Greenhouse gases. Carbon footprint of products. Requirements and guidelines for quantification.

based on its performance data, for example the amount of burned fossil fuels to generate a certain amount of electricity, without actually measuring the real emissions released by the activity (WRI & WBCSD, 2004).

Another point the standards seem to have widely in common are the principles they adopt when planning the operation of establishing a carbon footprint or an emission inventory. The focus is always on delivering a complete, consistent, accurate, relevant and transparent account for the carbon emissions associated with the investigated product (BSI, 2011; ISO, 2018a; WBCSD & WRI, 2011). Figure 5 provides an overview of the usually applied process, but each of the three main standards mentioned above will be presented separately as well.

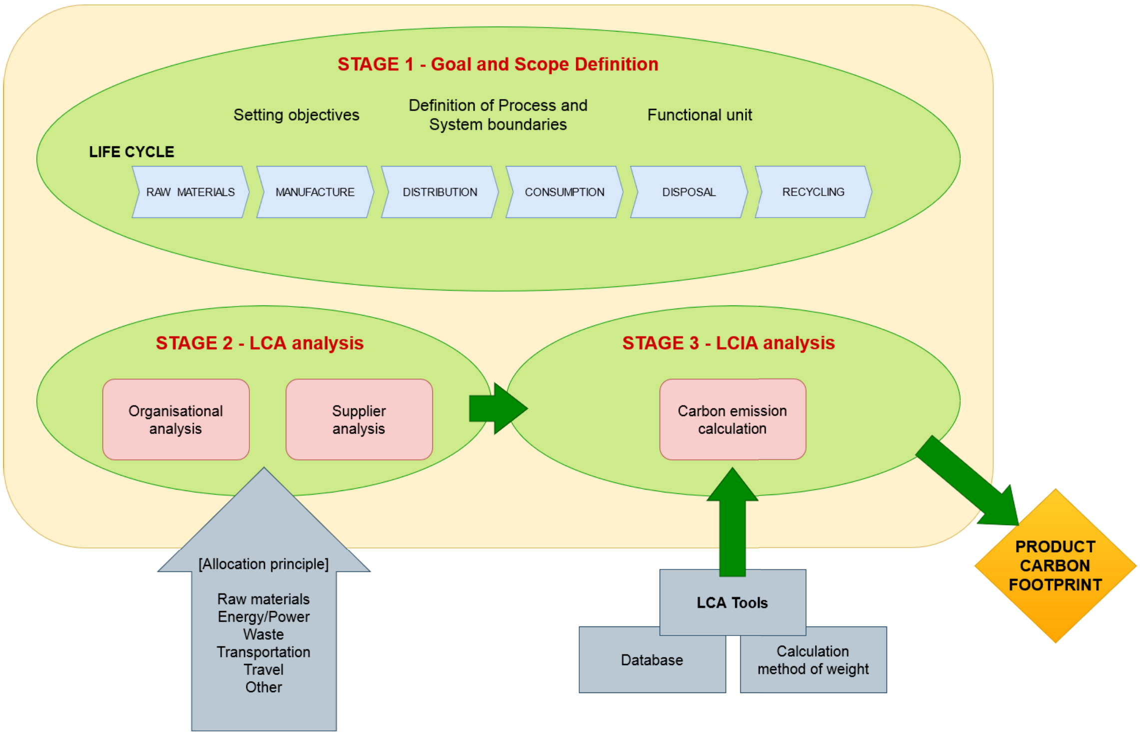

Figure 5. Schematic procedure for the calculation of a carbon footprint for products (retell Gao et al., 2014).

4.2.2.1 PAS 2050

Originally published in 2008, the PAS 2050 guideline draws heavily on the aforementioned ISO standards for LCAs and was the first international standard for product-related carbon footprints (Liu et al., 2016). Newer, reviewed versions of the standard are reportedly adjusted to fall more in line with the other major standards, GHG

Protocol and ISO 14067, as the development and revision process were strongly influenced by the developing process of the other guidelines. (WRI & WBCSD, 2019)

The PAS 2050 standard is a worldwide-useable approach for the assessment of services and goods offered by companies in relation to their caused emissions. The aim of the guideline is to offer a methodology to organisations that will allow them to consistently assess the impact of their products, analyse the results and subsequently use them to create mitigation plans to reduce the amount of emitted greenhouse gases. (BSI, 2011)

The procedure for carbon footprinting according to PAS 2050 consists of four different phases. At the beginning, the scope of the work needs to be defined, including the assessment of the life cycle of the investigated product and the determination of the system boundaries. The analysis of a product system could for example encompass the whole life cycle (cradle-to-grave) or focus on specific parts of the cycle (e.g. cradle-to-gate). (BSI, 2011) During the second phase, all relevant information and necessary data is collected. It is required to compile information of all specifically in the guideline listed 63 greenhouse gases for the carbon footprint assessment. In relation to that, the PAS guideline is promoting to first and foremost use as much as possible primary data sources, e.g. direct measurements, and only if they are not available to refer back to secondary data, e.g. provided by models. The assembled data is subsequently used in the calculation phase, where activity and performance information related to the investigated product are multiplied with appropriate emission factors, creating the final results for the emissions inventory, which is presented as carbon footprint. The global warming potentials needed for combining all gases to the same unit of CO_2 equivalents is based on the GWP for 100 years. (BSI, 2011)

The last phase consists of the interpretation of the obtained results. To promote the usefulness of the carbon footprint the standard suggests to not only take a look at the overall footprint but also to sort the results again into categories, for example in accordance with the life cycle steps, and calculate the share that the carbon footprints of the individual stages have in relation to the total carbon footprint of the product. This will especially come in handy when mitigation measures or climate action plans will be based on the results of the carbon footprint and hotspots need to be identified. The main interest for the final results is their preparation for external communication in relation to possible mitigation plans. In addition, the PAS 2050 standard is not opposed to include offsetting measures into those plans. (BSI, 2011)

4.2.2.2 GHG Protocol Product Standard

The accounting procedure presented by the GHG Protocol is organised in 12 steps, starting with the determination of goals for the investigated business and ending with setting up mitigation plans. The first step's aim is to help identifying appropriate data sources and methodologies, whereas the second and third step present the principles and fundamentals of the procedure ensuring that the conducted assessment will be carried out in a consistent, accurate and transparent way, preferably including the whole life cycle of the investigated product. The last two steps for preparing the basis before the actual accounting are the scoping and the definition of the product system's boundary. The GHG protocol demands the assessment of all emissions identified as greenhouse gases for example by the IPCC, including released and sequestrated emissions. (WBCSD & WRI, 2011)

The collection of activity data, preferably from primary measurements, and emission factors, as well as the allocation of the process flows in the product system and the addressing of possible uncertainties when collecting those information are the following three steps of the procedure. This leads then to the subsequent calculation of the carbon footprint with the results presented in CO_2 equivalents based on the GWP for 100 years. The inventory results need to be calculated for the whole life cycle, as well as for all product stages separately. (WBCSD & WRI, 2011)

Lastly, the GHG Protocol Product Standard also includes detailed strategies for reporting the results of the analysis (WRI & WBCSD, 2019). An important step during those final stages is the assessment of the GHG inventory by a third party (WBCSD & WRI, 2011). As the GHG Protocol is often used for voluntary emission accounting, the reporting part is more developed and additionally features advice on how to set up targets, maybe even on the long-run towards carbon neutrality, as well as establishing a tracking procedure of the progress that might be made over time (Liu et al., 2016). In addition, the GHG protocol does allow the reporting of offsetting measures as one strategy towards carbon neutrality. However, it is not allowed to include those compensation payments when calculating the carbon footprint. (WBCSD & WRI, 2011)

4.2.2.3 ISO 14067

The most recent version of the ISO 14067 standard was published in 2018 (ISO, 2018a), and while all three presented guidelines in this chapter are based on the ISO standards concerned with the Life-Cycle Assessment, ISO 14067 is the only one that specifically uses the exact same terminology. It refers to the different stages of establishing the carbon footprint as life-cycle inventory and life-cycle inventory analysis (ISO, 2018a), which are the terms defined in the LCA standards ISO 14044 and ISO 14040 (Klöpffer & Grahl, 2014), and makes concrete pointers to those standards as well (ISO, 2018a).

The calculation of the carbon footprint is carried out in four steps. During the scoping phase, a functional unit and the system boundaries for the investigated product need to be defined. During the life-cycle inventory stage, the standard requires the collection of all necessary data for the relevant input and output flows. It is stated that all relevant GHG emissions that need to be considered are the ones defined by the IPCC. For allocation and data quality purposes, ISO 14067 offers specific guidance and detailed instructions in relation to certain aspects like electricity usage or land-use change to ensure a correct application of the information. The life-cycle inventory analysis represents the actual calculation step, where activity data and emission factors are utilised to gather the final results for the carbon footprint in a mass unit of CO_2 equivalents in relation to the global warming potential of the other greenhouse gases. The last stage of the procedure is the interpretation phase. In addition to discussing the results and potential shortcomings of the calculation process, it is also required to examine the procedure in terms of consistency and completeness. (ISO, 2018a)

After the carbon footprint is calculated and the results analysed, the ISO standard requires the creation of a report detailing the whole process, as communication is a substantial concern of the methodology (Liu et al., 2016). The guidelines support the calculation of released emissions, as well as removals, for example due to land-use management. However, it explicitly omits carbon offsetting from its proposed methodology. (ISO, 2018a)

4.2.2.4 Overview of the guidelines

The following Table 1 outlines the characteristics of the three main guidelines for the calculation of a carbon footprint for product systems. It is mainly based on the specified standards (see BSI, 2011; ISO, 2018a; WBCSD & WRI, 2011), as well as Gao et al. (2014).

Table 1. Carbon footprint guidelines for products.

	PAS 2050	**GHG Protocol Product Standard**	**ISO 14067**
Organisation	BSI	WRI & WBCSD	ISO
Publishing year	2008, Revised 2011	2011	2018
Type	International Standard	Voluntary Standard	International Standard
Application area	Worldwide, Services and goods	Voluntary emission accounting	Reporting standard
'Inspiration'	LCA (ISO 14040 & ISO 14044)	LCA (ISO 14040 & ISO 14044) PAS 2050:2008	LCA (ISO 14040 & ISO 14044)
Principle	completeness, consistency, accuracy, transparency		
Which emissions?	63 listed GHG emissions	GHG emissions listed by IPCC	
What GWP?	100 year-GWP by IPCC		
Phases	1. Goal and Scope 2. Data collection 3. Calculation of CFP 4. Interpretation	1. Goals 2. Principles 3. Fundamentals 4. Scoping 5. Boundaries 6. Data collection 7. Allocation 8. Uncertainty analysis 9. Calculation 10. Checking results 11. Reporting 12. Setting targets	1. Goal and scope 2. Life-Cycle inventory 3. Life-Cycle inventory analysis 4. Interpretation
System boundary	Preferably: cradle-to-grave	Preferably: Whole life cycle	Whole life cycle
Data requirements	Preferably: primary data, Otherwise: secondary data		
Calculation method	Activity data x emission factors		
Unit	Mass unit of CO_2 equivalents	Mass unit of CO_2 equivalents	Mass unit of CO_2 equivalents
CFP	Whole process & individual life cycle stages		Mainly whole process
Offsetting	Not opposed	Separately reported, but not to be included in calculation of CFP	Explicitly omitted
Reporting	Usable for mitigation plans, focus on calculation but also external communication	In combination with setting up decarbonisation targes, Third party review beforehand	Creation of report required

4.2.3 Carbon footprint for organisations

When calculating the footprint on an organisational level, the most common guidelines are the GHG Protocol Corporate Standard[6], as well as the standards PAS 2060[7] and ISO 14064-1[8]. While the PAS 2050 from the British Standards Institution was the first one for products, the original standard for the organisational level is the one from the GHG Protocol, and especially the ISO standard used it as a starting point for its own approach (Harangozo & Szigeti, 2017). The basic methodology does not adopt the strategies from an LCA process but is adapted from an input-output analysis. (Gao et al., 2014)

The most commonly used process consists of four steps, with the first addressing the issue of choosing the organisational boundaries. This basically means defining what is part of the investigated organisation either in financial terms or based on ownership. Next is the operational boundary, set up in accordance with the different kinds of emissions (for example represented by the differentiation in three tiers; see WRI & WBCSD, 2004). The actual calculation of the carbon footprint happens in the third step, often featuring the usage of emissions factors similar to the procedure applied to products or is based on results from models and measurements. The last step includes the issue of reporting the carbon footprint, as well as verifying the results. (Gao et al., 2014; ISO, 2018b; WRI & WBCSD, 2004) Figure 6 depicts the main structure of the procedure. The three main guidelines for the organisational level will be presented separately.

[6] Greenhouse Gas Protocol - A corporate accounting and reporting standard. (2004)
[7] PAS 2060:2014 - Specification for the demonstration of carbon neutrality.
[8] ISO 14064-1:2018 - Greenhouse gases. Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals.

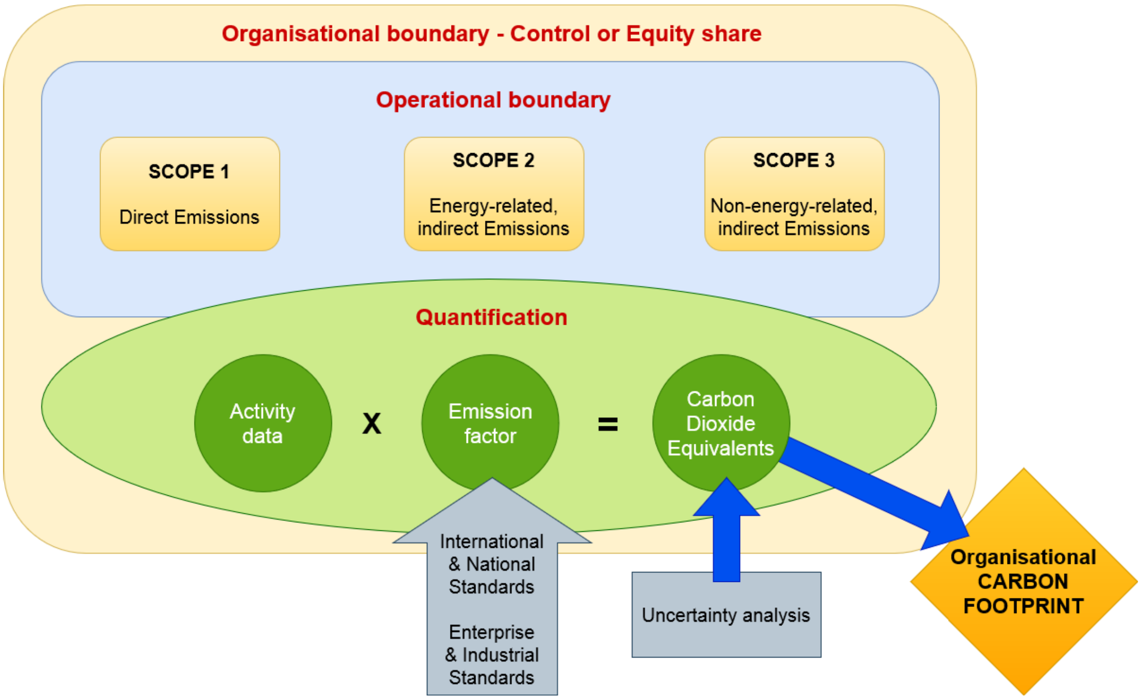

Figure 6. Schematic procedure for the calculation of a carbon footprint for organisations (retell Gao et al., 2014).

4.2.3.1 GHG Protocol Corporate Standard

The procedure outlined above is mainly adopted by the GHG Protocol Standard, from which it also originated. The most recent guideline was published in 2004. For the first step, deciding on the organisational boundary, the GHG protocol defines two different, appropriate approaches: the frame for the organisation is established based on either control - emissions are counted in if the organisation has control over the ones responsible for them being emitted - or economic interest - emissions are considered based on the equity share an organisation has in a project. (WRI & WBCSD, 2004) When the operational boundary needs to be determined during the second step, the focus is on the scope of the emissions. The GHG Protocol assumes a split of emissions in three tiers: direct emissions, indirect emissions related to generation of energy and the remaining indirect emissions. The focus is mainly on the emitters. (WRI & WBCSD, 2004) During the analysation of the emissions inventory, it is the greenhouse gases defined in the Kyoto Protocol that are taken into consideration by the guideline (Gao et al., 2014). This includes carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride (WRI & WBCSD, 2004).

The procedure continues with regulations for acquiring the necessary data to handle the actual calculation. Primary data, i.e. derived from direct measurements, or secondary data, e.g. collected from models using mass balances or stochiometric approaches, and emission factors taken from official databases make up the basis for the calculation, considering that the main approach for that is the multiplication of activity data and emission factors. (WRI & WBCSD, 2004) The GHG protocol offers sector-specific or cross-sectional calculation tools on their webpage for that part consisting of worksheets where the collected data can simply be inserted, and the final carbon footprint is worked out. The results are presented in a mass unit of CO_2 equivalents. (WRI & WBCSD, 2004). Another important part of the methodology is the setting of a base year, preferable a time when the available emission data can be verified. This enables the organisations which carry out the carbon footprint assessment to compare their performance over time. In case the boundaries have to be changed during subsequent calculations, for example if the organisation is undergoing structural changes, there is an option for reviewing the results of the base year as well, ensuring consistency. The comparison can be used for tracking mitigation targets and help defining new or improved reduction plans. (WRI & WBCSD, 2004)

Finally, the GHG protocol includes a section on how to process the results and prepare them for publishing or reporting, as well as how to ensure the appropriate quality of the GHG inventory. Similar to the principles of the carbon footprint for products, the approach for organisations wishes to provide the user with the means to carry out a transparent, accurate, complete, and consistent calculation process. In that spirit, the guideline presses the point that it is very important to search for errors, obvious mistakes and inconsistencies in the data collection during the documentation process and when doing the actual calculation, as this will help establishing a good quality for the GHG emission inventory (WRI & WBCSD, 2004).

The GHG protocol is most often utilised in a voluntary context, for example in combination with the utilisation of voluntary carbon trading markets. The standard pays extra attention to the analysis part when defining the emissions inventory, with more information on how to define activity data and emission factors, but it also provides guidance on how to report the final results of the carbon footprint accounting. (Gao et al., 2014)

4.2.3.2 ISO 14064-1

The ISO 14064-1 standard was developed in close relation to the GHG Protocol Corporate Standard (Gao et al., 2014) and the most recent version was published in 2018 (ISO, 2018b). There are not many differences between those two guidelines and the main aspects all closely resemble each other. The proposed procedure for calculating a carbon footprint consists of seven main steps (ISO, 2018b).

During the first stage, the boundaries for the assessed system are defined. The organisational boundary is set in accordance with either the share of control or equity. Additionally, the reporting boundary (similar to operational boundary) is determined by settling on the emissions that will be included in the analysis. The assessment follows the scopes of emissions split into direct and indirect emissions. Furthermore, inventory categories for the emissions are defined, only roughly resembling the commonly applied three-tier structure. The indirect emissions are separated in six categories, including especially emissions generated due to the needed energy, the transportation, and the usage of products by the analysed corporation. (ISO, 2018b)

The second phase of the methodology introduces the collection of data. It is allowed to utilise direct measurements, as well as information derived from modelling. The ISO standard explicitly emphasises the inclusion of carbon sinks and emission removals in the analysis alongside the emitted GHG emissions in all previously defined inventory categories. For the relevant gases the standard refers to the most recently available publication of the IPCC. The assembled primary performance data or the secondary activity data with the relevant emission factors are utilised in the third phase, the actual calculation of the carbon footprint. The preferred unit for the result is tonnes of CO_2 equivalents using the 100-year GWP published by the IPCC. (ISO, 2018b)

Subsequently, the ISO standard presents rules on how to establish an appropriate base-year inventory that will be utilised for assessing the future efforts in mitigating GHG emissions. To ensure consistency, the guideline provides the option for reviewing those results later on, for example if the organisation is undergoing changes that would lead to different system boundaries. Furthermore, it is also encouraged to utilise the standard in combination with establishing mitigation targets, excluding however offsetting payments. The last steps of the ISO methodology include the assessment of quality for the conducted process and the final carbon footprint, as well as the reporting of the results. (ISO, 2018b)

The main area of application for the ISO standard is in connection with compulsory reporting mechanisms for example set by governments. Therefore, the methodology presents specific instructions on how to report the results. (Gao et al., 2014)

4.2.3.3 PAS 2060

The PAS 2060 standard differs from the originally established procedure used by the GHG Protocol and ISO 14064-1. A major difference is the fact that the main focus of the PAS guideline is the management of offsetting measures in relation to the greenhouse gas emission inventory of a company or organisation. It can be said that the whole process basically revolves around the goal to properly offset emissions and the standard outlines the process of achieving carbon neutrality with a clear focus on including said offsetting measures. In this context, establishing a carbon inventory and calculating a carbon footprint is treated as a means to an end. (NQA, 2020) The PAS 2060 standard consists of four major stages. The first provides information on how to conduct the required measurements for the GHG inventory, which has to be comprised of at least 95% of the company's total emissions (NQA, 2020), but definitely all emissions of tier 1 and 2 (ecoact, 2020). At this point, the guideline directly refers to the other two relevant standards and promotes their usage for this part of the process. Considering ISO 14064-1 and the GHG Protocol Corporate Standard this would relate to their steps 1 to 3, leaving out only the reporting step.

Instead, PAS 2060 follows up with a second stage where a mitigation plan is to be created with the end goal equalling carbon neutrality. Next up are considerations for deciding on appropriate offsetting measures. The standard stresses that only accredited and trustworthy offsetting schemes and projects are to be selected. It lists among others EU Allowances, the Gold Standard (refer to chapter 4.3 'Connection between carbon footprint and offsetting measures'), and the Verified Carbon Standard as possibilities. The last stage of the procedure refers to how the GHG inventory, the offsetting measures, as well as the climate action plan of the organisation should be documented and published. (NQA, 2020) As one of the main motivations for following the PAS 2060 is stated as improving the confidence of customers in the earnestness of the company to reach carbon neutrality, transparency for reporting (ecoact, 2020) and the publication of annual mitigation plans (NQA, 2020) is of utmost importance.

The PAS 2060 is the only internationally available and accepted certification methodology for proofing the carbon neutrality of an organisation or company, and is often chosen as standard by carbon labels for organisations (e.g. TÜV 'Carbon Neutrality' (Castro, 2020), more details in chapter 4.4 'Certifying carbon neutrality'). The standard is especially built to cater to the needs of companies wanting to voluntarily commit to certain emission mitigation goals. (ecoact, 2020)

Figure 7 visualises the process adopted by the PAS 2060 guideline, as the previous figure presenting the approach for organisations (see Figure 6) is not showing the whole procedure.

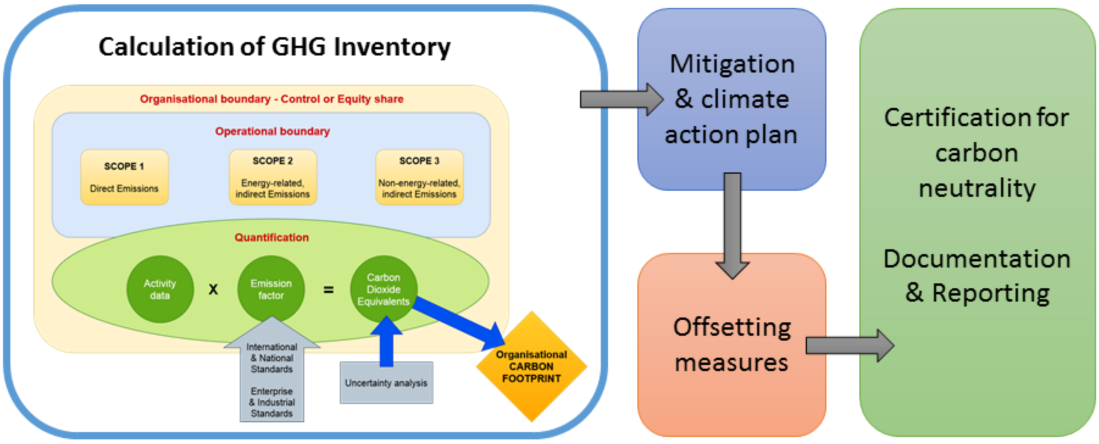

Figure 7. Schematic procedure of achieving carbon neutrality in accordance with the standard PAS 2060 (partial retell Gao et al., 2014).

4.2.3.4 Overview of the guidelines

The following Table 2 provides an overview of the three standards previously introduced for the calculation process of a carbon footprint on an organisational level. The main references utilised are the guidelines for the procedures (see ISO, 2018b; WRI & WBCSD, 2004), explanatory reports on the PAS 2060 standard (see ecoact, 2020; NQA, 2020), as well as a published assessments of the guidelines (see Gao et al., 2014; WRI & WBCSD, 2019).

Table 2. Carbon footprint guidelines for the organisational level.

	PAS 2060	GHG Protocol Corporate Standard	ISO 14064-1
Organisation	BSI	WRI & WBCSD	ISO
Publishing year	2010, Revised 2014	2001, Revised 2004	2006, Revised 2018
Type	International Standard	Voluntary Standard	International Standard
Application area	Certifying carbon neutrality (for voluntary commitments)	Voluntary emission accounting	Reporting standard
'Inspiration'	Partly GHG Protocol Corporate Standard	-	GHG Protocol Corporate Standard
Principle	completeness, consistency, accuracy, transparency		
Which emissions?	GHGs reported in the Kyoto Protocol		GHG emissions listed by IPCC
What GWP?	100 year-GWP by IPCC		
Phases	1. Carbon Footprint 2. Mitigation plan 3. Offsetting measures 4. Documentation and publication	1. Organisational boundary 2. Operational boundary 3. Data collection 4. Calculation 5. Processing results 6. Checking for inconsistencies 7. Optional reporting	1. Organisational and reporting boundaries 2. Data collection 3. Calculation 4. Interpretation of results 5. Checking for inconsistencies 6. Reporting
Organisational boundary	Equity share or control share		
Scope of emissions (operational boundary)	3 tiers: Direct emissions, Indirect emissions from energy generation, Remaining indirect emissions		6 categories: Direct emissions, Indirect energy-related emissions, 4 categories for remaining indirect emissions
Data requirements	Primary and secondary data		
Calculation method	Activity data x emission factors	Activity data x emission factors, Specific calculation tools offered	Activity data x emission factors
Unit	Mass unit of CO_2 equivalents		
Offsetting	Purpose of the guideline	Separately reported, but not to be included in calculation of CFP	Explicitly omitted
Reporting/Purpose	Proof for carbon neutrality	Useable for voluntary carbon trading markets	Creation of report required

4.3 Connection between carbon footprint and offsetting measures

One example on how the carbon footprint and offsetting measures might be connected can be seen by the promoted offsetting procedure of certification association such as Gold Standard. At the beginning of the process, the carbon footprint needs to be calculated. For a personal footprint, using for instance the WWF carbon calculator is suggested. Based on the calculated results, given in tonnes of carbon dioxide equivalents, the number of needed offsets to reach net-zero emissions is determined. Those necessary compensations can be bought directly from the marketplace operated by Gold Standard. The association promotes a range of different projects, featuring for example the construction of wind power plants, providing cleaner cook stoves to countries of the global south or the regeneration of forests. Prices per tonne of emissions range from 10 to 50 USD (as of February 2021). The service is offered for individuals but also for businesses and organisations. (Gold Standard, 2021) This approach is one of the most commonly used methods to introduce carbon offsetting measures, illustrating the direct relationship between footprints and compensation. In the voluntary carbon markets the traded emissions are often referred to as ‘credits’, a market-equivalent to the traded tonnes of emissions (Vidal, 2019).

Offsetting is mentioned in some of the guidelines introducing the calculation methodologies for the GHG emission inventory. As previously mentioned, the PAS 2060 standard promotes actively the usage of offsets, following the procedure of first calculating the footprint, then planning mitigation measures and lastly buying compensation for the remaining emissions that are currently not or only difficult to decrease. The Gold Standard is listed as one of the certified emission reduction measures that can be used in compliance with the PAS standard. (NQA, 2020)

4.4 Certifying carbon neutrality

In addition to evaluating the effort for reaching carbon neutrality, the utilisation of certifications for those who have already achieved a net zero greenhouse gas emissions balance based on the most popular guidelines for calculating carbon footprints could be an advantage. In terms of tracking the precise progress and allowing for official statements, it is beneficial that some parts of the performance of countries or cities is more or less transparently visible. This is for example the case with GHG emissions inventories, due to the fact that many countries maintain national statistics, where such data is published on a regular basis. Examples are Eurostat showing national statistics for the member states of the EU (European Commission, 2019a) or Statistics Finland, responsible for the monitoring and publishing the GHG emissions in Finland (YM, 2021). On the other side are organisations or companies in the private sector, as well as educational institutions which do often not report their emissions in a similar, official way. In general, the close monitoring of efforts towards carbon neutrality and the comparison of goals and performance could proof beneficial for future progress in mitigating climate change as it can act as a positive incentive for competition, especially when the awareness of the world's population for climate topics keeps on rising.

In addition to initiatives that follow up on the progress made by countries, cities, or institutions, one possible way to support the rising of awareness to the issue of global warming and the necessary countermeasures could be labels and certifications published by various organisations. The basic standards utilised for such endeavours include the guidelines for Life-Cycle Assessment or Environmental Impact Assessment, as well as the GHG Protocol guidelines and the Publicly Available Specification (PAS). Several countries have their own carbon labels introduced by supermarket chains, private companies or similar, and many are based on those most popular standards. However, the majority of the labels are focusing on (food) products, which the greater number of them already introduced in the late 2000s. (Liu et al., 2016) The majority of guidelines, rules, and tools for certifying carbon neutrality or accounting the emissions are designed for processes and products, not so much for whole institutions, people, or countries. A possibility that is offered, often based on the aforementioned guidelines, is a carbon footprint assessment. Given its nature it is possible to adjust the calculation to also fit other objects of investigation instead of only specific products or processes.

In relation to that fact, there is a growing number of organisations in recent years that issue certifications not only for products or processes, but also for whole companies, events, or organisations. One of those is the German TÜV SÜD 'Carbon Neutrality' certification. It is based on the PAS 2060 guideline and promises a realistic assembly of the greenhouse gas inventory and the acknowledgment of existing climate action plans. In addition, offsetting programs are only accepted from credible compensation projects. The first step for receiving the certification is the assessment of the GHG emissions, followed by the planning of mitigation measures and the subsequent purchase of offsets for emissions that can't be avoided. (Castro, 2020) Similar options are offered by Carbon Connect (carbon-connect AG, 2020) or the CO2-Neutral® label (2020), the latter specialising in certifying businesses.

The label provided by carbon connect is based on the ISO guidelines 104040 and 104044 for Life-Cycle Assessments, as well as ISO 104067 for carbon footprints, and the GHG Protocols. Emissions for all scopes are taken into account and the net zero balance certified by the label is achieved via compensation payments. (carbon-connect AG, 2020) The CO2-Neutral® label refers to the GHG Protocol approach and requires in addition to the calculation of the carbon footprint the development of a management plan for the emissions. Mitigation measures and offsetting are promoted for addressing remaining emissions. The certification is supposed to help communicating the business' effort to the customers. (CO2-Neutral-label, 2020) A commonality of all labels is the promised benefit that a third-party assessment via the label providers will ensure the credibility of the climate actions (carbon-connect AG, 2020; Castro, 2020; CO2-Neutral-label, 2020).

Other possibilities for creating attention to commitments are the official announcements of networks or alliance that showcase who of its members already achieved their goals. An example for that are the listed carbon neutral universities in the USA by Second Nature (2020) or the previously mentioned alliances formed by cities around the world.

5 THE CARBON HANDPRINT – A DIFFERENT TAKE ON THE FOOTPRINT CONCEPT

As depicted in the previous chapter, the carbon footprint is nowadays a popular tool with various established guidelines and methodologies. The related calculations provide the basis for carbon neutrality and the development of mitigation plans are most likely going to start from its perspective. In contrast to that there is also a newer, less commonly used tool for assessing impact and reduction of GHG emissions: the carbon handprint. The following section will explore the concept of the handprint, give insights in the methodology and describe how it is related to the carbon footprint.

5.1 Concept and idea of the handprint

The handprint is a more recently developed methodology that focuses on assessing the positive impact that certain actions, products, or activities can cause. It therefore stands in direct contrast to the footprint where especially negative impacts are analysed. In general, the handprint is associated with the notion ‘to do good things’. (Grönman et al., 2019; Norris, 2015; Vatanen et al., 2018) The handprint was introduced as a new concept for the first time in 2007 during an UNESCO conference (Grönman et al., 2019). At that time, it was supposed to symbolise actions undertaken for improving environmental and social issues. Among others, Biemer et al. (2013) picked up the idea and produced an approach that was trying to encompass personal actions in an accounting concept. Those actions can include activities like planting trees or recycling in a proper fashion, as well as encouraging others to follow an environmentally-sound lifestyle, increasing at the same time one’s own positive impact. (Biemer et al., 2013) The first ideas of handprint concepts were not focusing on specific products or processes, but solely on personal actions and contributions, showing that the approach was developed more from an educational point of view. Those earliest approaches have the problem that while identifying the handprint impacts might be feasible, the difficult part occurs when one is asked to quantify this positive impact with the goal to provide some kind of value to use it in comparison with others or with the negative impacts calculated by the footprint. (Vatanen et al., 2018)

More recent definitions differ slightly from the personal and education-based approach. Basically, as soon as there are calculation approaches, the definition is changed to more tangible subjects, not so much social actions but more measurable improvements. The theory of assessing positive impacts might stay the same as seen by a recent analysis on the handprint approach by Guillaume et al. (2020) but the definitions vary from each other in the details. It can be said that there are two major approaches on what the handprint means, largely depending in what context it will be applied. The first puts the focus on social, often personal, actions and aspects. It is for example promoted by Biemer et al. (2013), as mentioned above, and Reif & Weischer (2015). The latter suggest that what creates a handprint are social actions that make a difference, inspire fellow human beings, and change the society, based on political engagement and reformation in a more sustainable way. They award such a behaviour an equal importance compared to reducing one's footprint: after the footprint is mitigated, a person should try to leave an even bigger and positive impact by establishing a handprint. (Reif & Weischer, 2015) The second approach is trying to provide a consistent framework based on more calculable impacts and with a technological background instead of primarily focussing on educational impacts. Researchers from the Finnish research institute VTT have recently worked on a carbon handprint guide where the focus is on a comparison of certain products based on baseline footprints and handprint opportunities. The methodology draws its framework mainly from the approaches presented for carrying out a life-cycle assessment. (Pajula et al., 2018; Vatanen et al., 2018). A part of the concept presenting a socially focused viewpoint can be found in the more technologically orientated approach as well: the impact assessment is consequently carried out from the consumer's or customer's perspective (Vatanen et al., 2018). This is one of the core principles associated with the handprint. It is not per se the improved product or technology that brings the positive change, but the humans using it depending on their context and manner of utilisation (Norris, 2015).

5.2 Relation between footprint and handprint

In general, the handprint is derived in its basic structure from the footprint but takes the concept even further by also including the actual consumer in the assessment. If a product has simply decreased its impact during manufacturing or similar life cycle stages, this would count as mitigation of the footprint and not necessarily as handprint. Only by helping others reducing their footprints, a handprint impact is created. Therefore, in contrast to the footprint, the real impact is mainly achieved in the end-use stage. The decreased amount in the footprint during the usage of a product can on one hand be allocated as footprint mitigation to the consumer, but at the same time as positive handprint impact to the company who produced the product the consumer is using. This also highlights the fact, that a handprint can only be calculated in comparison to a baseline, which is the footprint of another product/technology or an earlier version of the same product/technology. Basically, the company has the chance to reduce the impact of their products by for example reducing the waste or the amount of needed energy, by making more sustainable choices of material and by increasing the performance and the lifetime of a product, always in comparison to a baseline product. This decreased footprint, transferred to the customer, is the first option of creating a handprint. The second approach is to develop technologies that will have a smaller footprint during the usage phase, therefore directly improving the customers performance in relation to the baseline. The handprint is always calculated from the perspective of the consumer or customer and then allocated to the organisation or company who enabled the reduction of the customer's footprint in the first place. (Grönman et al., 2019) Both approaches for achieving a carbon handprint are depicted in Figure 8.

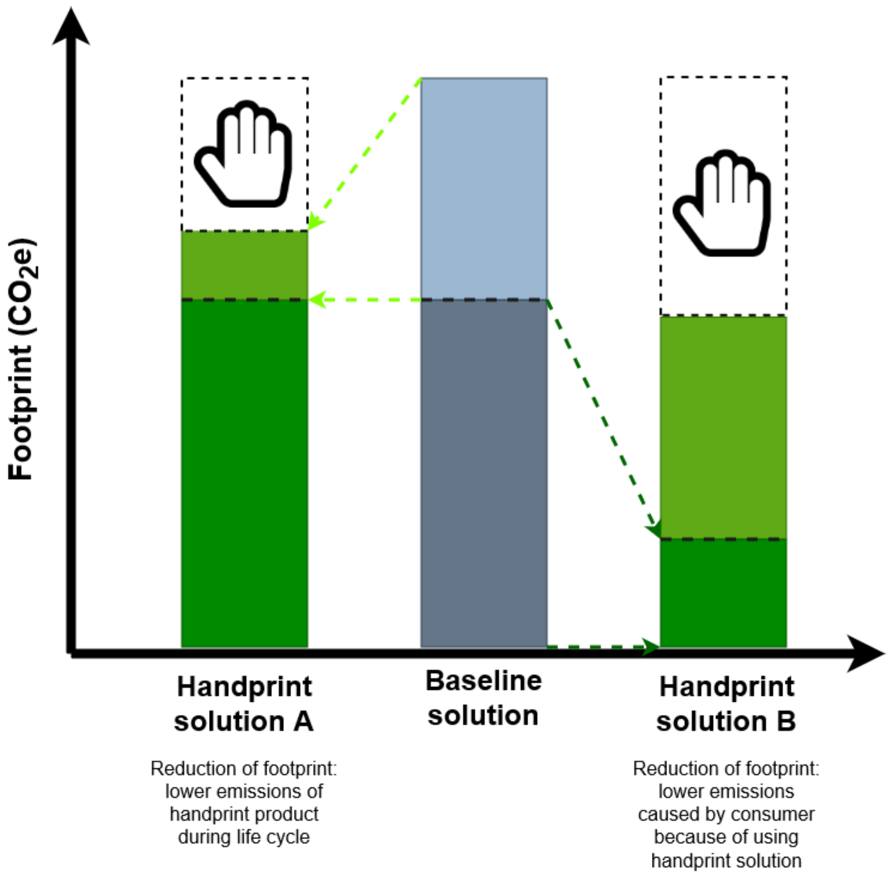

Figure 8. Visualisation of the handprint concept in relation to the baseline carbon footprint (retell Vatanen et al., 2018).

In Figure 8, the baseline solution consists of two parts that are responsible for emitting greenhouse gases: the manufacturing of the product with all related downstream and upstream activities (upper part), as well as its usage by the consumer (lower part). Handprint solution A causes less emissions during the manufacturing of the product, which therefore leads to a lower CFP for the customer buying this product - the upper part of the CFP is reduced compared to the baseline solution. Handprint solution B on the other hand, has the same emissions during the manufacturing, but its usage causes less emissions, leading again to a CFP reduction for the consumer and a handprint for the company – the lower part of the CFP is smaller in comparison to the baseline product.

Handprints can be generated in combination with different versions of footprints and all kinds of environmental impacts, at least in theory. Currently, the focus is mainly on approaches that are based on the carbon footprint and therefore on the mitigation of GHG emissions. But as long as there is a baseline calculation available, a handprint can be potentially established as well for other kinds of impacts. (Pajula et al., 2018)

5.3 Methodology for calculating a carbon handprint

The calculation method presented in this chapter mainly follows the guidelines and papers associated with the Finnish research project “The Carbon Handprint Project” carried out by VTT (see Pajula et al., 2018; Vatanen et al., 2018). There are other relevant projects as well which developed approaches to calculate a consistent handprint, like the German Handprint Research Project (Kühnen et al., 2019). The general approaches are similar, but due to the fact that the guidelines published by VTT were already applied to at least two real-life cases (renewable diesel by Grönman et al., 2019 and air pollutants from paraffinic diesel by Lakanen et al., 2021) they were given the most attention.

A carbon handprint is first and foremost calculated in strong relationship to a baseline carbon footprint. After calculating footprints for the baseline and the improved object, they are subsequently compared to each other and the positive difference generated by an emission mitigation for the consumer or customer is then defined as the handprint. (Pajula et al., 2018) This procedure is depicted in formula (1) (Grönman et al., 2019):

$$\text{Carbon handprint} = \text{CFP}_{\text{Baseline}} - \text{CFP}_{\text{Improved Object}} \tag{1}$$

As can be seen from the formula, establishing a handprint requires the calculation of two separate footprints. With the focus settled on the assessment of products, the calculation process is based on the standards ISO 14040 and ISO 14044, which are outlining the procedure for a Life-Cycle Assessment, as well as ISO 14067, the guideline for carbon footprinting for products (Pajula et al., 2018).

At the beginning of the calculation process, the product that will be investigated and the consumer's context need to be decided on. After the potential way of how an assessed object could provide a mitigation effect is identified, an appropriate baseline product is chosen. It is important that baseline and improved object have the same function, can both be found on the market, and are used in the same chosen geographical location and time frame. The aforementioned steps make up stage 1 of the process. In stage 2, staying true to the methods defined for an LCA, the next step is to define the functional unit of the products and the system boundaries with the relevant life-cycle stages. Drawing up a flow diagram is considered beneficial as well. Similar to an LCA process, certain life-cycle parts can be omitted from the overall assessment in case they are exactly similar between the two compared objects. Last step for this stage is the selection of appropriate sources for the required data. The third stage consists of the actual calculation of both footprints and subsequently, the handprint. During the last stage, the results will need to be verified and critically reviewed, to prepare them for publication. To allow a consistent comparison with the carbon footprint, the preferred unit for the carbon handprint is as well a mass unit for carbon dioxide equivalents. (Grönman et al., 2019; Pajula et al., 2018)

An important aspect that needs to be taken into consideration is the fact that the handprint methodology does not favour the usage of offsetting measurements. Mitigations in emission rates of a product that were achieved due to offsetting part of the emissions are not allowed to be included in the carbon footprint calculations and therefore don't play a role for carbon handprinting. (Grönman et al., 2019) In addition, the choice of consumer and end-use context is very important for the final results. Its characteristics will greatly influence the outcome. For that reason, there can be varying handprints for one and the same product depending on the different customers. The baseline remains untouched by those changes, but the handprint solution will depend on the characteristics of the consumer. (Vatanen et al., 2018) The final results of the handprint strongly depend on the chosen definition and scope of the calculation. The utilised baseline plays an important role, as well as the decision whether to include footprint mitigations as positive handprint impacts or not. In addition, the outcome is influenced by the characteristic of the investigated object and will change depending on whether a singular product is assessed or a whole organisation, with individual products and services only making up a part of the whole impact. In case several actors are involved in the same positive impact, the final handprint will be determined by how the impact is allocated between them. Lastly, the definition of boundaries has another important effect on the end-results, as it shifts the amount of emissions belonging to the system. (Guillaume et al., 2020)

5.4 Example of a carbon handprint

As part of the guideline published by VTT for their handprinting concept, a number of exemplary case studies were presented (Vatanen et al., 2018). To illustrate the methodology described in the previous chapters, one of those examples will be recounted here as well.

One of the case studies analyses the opportunity of creating a carbon handprint by introducing a new kind of shopping bag to customers of supermarkets and other stores in Finland. The bag is biodegradable and the manufacturing process releases less GHG emissions as the one of a comparable, conventional plastic bag. (Vatanen et al., 2018)

The first step for creating a handprint for this case is to determine the characteristics of the customer. As pointed out for example by Grönman et al. (2019), the handprint is always calculated from the perspective of the consumer and then applied to the manufacturer of the product. The research team of VTT identified at least six different customer profiles that could be used for the handprint. Their differences are based on how the product is utilised, meaning for instance whether the bag is re-used and what happens at its end-of-life stage. For this example, the one-time usage of a shopping bag that is subsequently incinerated was set as consumption profile. From this follows that the baseline carbon footprint will be calculated for this same kind of utilisation of a plastic shopping bag and the carbon footprint of the improved object will be the biodegradable bag with that usage. Potentially, a handprint could be realised because of the lower GHG emissions associated with the new shopping bag compared to the conventional solution in either manufacturing or during the incineration. (Vatanen et al., 2018)

After the specifications of the investigated objects are determined, the functional unit and the system boundaries are set up. The calculations will be carried out for one bag of a specific weight and due to the fact that the end-of-life scenario was chosen to be the incineration, specific data for this process will be assembled alongside other relevant manufacturing information needed to assess the product from cradle-to-grave. Based on the collected data, the carbon footprints of both bags are calculated. The guidelines that are supposed to be followed on that point are the ISO standards for LCAs and the carbon footprint for products. By subtracting the end results from each other (see formula 1), the potential handprint is created. (Vatanen et al., 2018)

As this example was carried out based on real products, the final results depicted actual values, showing a reduction of over half in the mitigated emissions for the biodegradable bag compared to the baseline product. The main contributor for the handprint is in this case the decreased carbon footprint of the improved bag (option A of Figure 8), as the usage (option B) does not differ between the two analysed bags. By offering a packaging option with a lower carbon footprint to customers, the manufacturer achieved a carbon handprint for their product. The last stages after the calculation would be a critical review of the assessment, as well as the reporting of the results. (Vatanen et al., 2018)

5.5 Utilisation of the handprint

Grönman et al. (2019) refer to the handprint primarily as marketing tool for companies. The handprint could be used to prevent the notion of greenwashing for businesses and their products (Grönman et al., 2019; Vatanen et al., 2018). Where carbon footprints only show the emitted emissions, meaning the negative impact, the carbon handprint would provide the positive effects. Companies, claiming that their technologies can help fighting the climate change from the consumer’s point of view or are more environmentally friendly then competing technologies would be, now have actual numbers to proof that they are not just greenwashing. However, Kühnen et al. (2019) pointed out that publishing the handprint will only help if the calculations, used methodology and the individual results for the utilised footprints are presented in a transparent way as well. This is especially important in the light of possible manipulations used for greenwashing as seen with carbon footprint labels (Liu et al., 2016). To ensure the correctness of the handprint calculations and raise its credibility, Vatanen et al. (2018) suggest the inclusion of a third, independent party that controls and verifies the undertaken handprint procedure. This is quite similar to the call for third party verification of carbon footprints included in the GHG guidelines (WRI & WBCSD, 2004) or PAS (NQA, 2020) and ISO standards (ISO, 2018b).

Furthermore, handprints can be used to not only signify a certain mitigation of GHG emissions but might also open up the possibility to become 'net positive', which is another way of formulating the terms carbon or net negative and used in some cases in relation to the handprint theory. The net positivity was discussed at length by Norris (2015) and picked up again among others by Debaveye et al. (2020), where it was defined that it can be reached when the positive impact of the handprint outweighs the negative impacts of the footprint. This is especially meaningful when considering that a carbon footprint can only be reduced and the likelihood to reach true zero (not only in balance) is rather small. The impact the mitigation of emissions and the subsequent decrease of the footprint can have is limited. The handprint on the other hand is calculating its impact in the other direction – a positive impact of reduced emissions – and can therefore be seen as limitless (Pajula et al., 2018) and as potential tool that enables the achievement of net positivity without relying on offsetting measures. So far, the handprint is the only tool that recognises positive impacts (Pajula et al., 2018).

5.6 Benefits and limitations of the handprint approach

5.6.1 Benefits

When considering the question why a handprint should be calculated, several researchers point out that negative impacts are often seen in a pessimistic way whereas positive impacts might be able to encourage more people to take up action. The handprint could prove that solutions are developed and the climate change is being addressed. (Guillaume et al., 2020; Vatanen et al., 2018) In that way, researching positive impacts could lead to the discovery of win-win situations: the investigated object itself is already providing an improved solution, becoming less unsustainable, and at the same time solutions for a more sustainable future are presented as well (Kühnen et al., 2019).

With the strong link to consumer behaviour in the calculation of the handprint, this methodology could also help to identify possible lacks of conformity between the manufactured product and its real-life usage (Grönman et al., 2019). In addition, while a footprint shows the emission rate of a product or organisation and might be compared with others, it is more difficult to see in what way it could be mitigated (Guillaume et al., 2020). Handprints can help to identify those relevant potentials, but might also demonstrate that some mitigations along the life cycle stages do not lead to any positive impacts (Grönman et al., 2019). On the other hand, strengthening the consumer's perspective and taking it into consideration early on in the decision-making process and the development of new products and technologies could lead to the recognition of long term climate-friendly choices as beneficial for a company or organisation (Grönman et al., 2019).

5.6.2 Limitations

While the handprint offers a number of benefits, there are some limitations associated with it as well. First of all, the calculation procedure is most likely more time-consuming compared to the footprint calculation. The main reason is that the handprint requires at least two separate footprints and subsequently the comparison of both, resulting in a handprint. In addition, the term 'handprint' is currently not used in the same capacity as the footprint and therefore sill quite unknown. This might undermine its current potential. Lastly, the whole handprint rises and falls with the choice made for the baseline footprint. If the chosen product was not appropriate, the end-results of the positive impact are completely unreliable. (Grönman et al., 2019)

5.6.3 Handprinting for assessing operations in an educational context

The creation of a handprint seems like a good option to be integrated in assessing the impact of an organisation, especially considering the benefits mentioned above. However, using handprints for the evaluation of the climate-related impacts of a university or a campus area might still provide considerable challenges at the moment. Handprint concepts are currently focused on providing calculation tools for products and services (Vatanen et al., 2018), not so much for the organisational stages. Due to the complexity of a technology- or product-based handprint, it can be expected that the calculation would be more difficult for abstract objects like the positive impact of research, education, or scientific papers, as those are mostly subjects without calculable values. The concept of VTT's handprint approach is following the guidelines for an LCA study (Pajula et al., 2018) and as depicted in a previous chapter the standard behind this methodology requires precise and consistent data to ensure accuracy (ISO, 2006). Defining baselines, scopes and calculable values of improvement, as asked for the creation of a handprint (Guillaume et al., 2020), will be difficult to obtain in a research or education context.

Despite the currently still existing limitations of this approach to quantify positive impact, the bottom line is that the handprint is a useful complementing tool for the utilisation of footprints and might broaden the perspective the people have of mitigation measures and a more sustainable future (Guillaume et al., 2020).

6 CONCEPTS FOR A CARBON NEUTRAL CAMPUS

Mitigating emissions and reaching carbon neutrality takes up an important role in the fight against climate change. Following international treaties and commitments issued by various alliances, entities like countries, cities, and organisations are looking to adopt related goals. In addition, guidelines for implementing action plans are published and methodologies for analysing GHG emission inventories or carbon footprints are developed. Those aspects were depicted in the previous chapters. Yet, the level of commitment varies greatly – the urgency to act is not recognised by everyone, marking the need for trailblazers and pioneers. A big consensus in the academical world seems to be that institutions of higher education have the responsibility to become those forerunners for climate friendly practices and should aim for establishing sustainability on their premises and for their operations, with carbon neutrality being an integral part of the endeavour (see for example Getzinger et al., 2019; Gómez et al., 2016; United Nations, 2020b).

In addition, as place for education and research, universities are also identified to have the possibilities to achieve progress independently from national laws or mandatory obligations by adopting new technologies and practices supported by their own research and community. As one of their tasks is to educate and prepare the young generation, the possibilities to influence the public opinion can't be neglected and should be used to increase the understanding for the necessity to become carbon neutral and more sustainable. Universities and similar institutions making official commitments towards net zero emissions would help spreading the message to other organisations or to governments, showing the willingness to act and to fight the climate change. (Disterheft et al., 2012; Gómez et al., 2016; Udas et al., 2018; UNIFI, 2020)

When thinking about a carbon neutral campus, there are two main objectives that need to be considered. The first is the question which pathway or methodology should be chosen to reach the goal of a net zero balance of emissions and how different tools, as for example the carbon footprint can be utilised in the process. The second one tackles the topic what kind of commitments should be made and how various institutions are handling the matter of reaching carbon neutrality on campus. Both aspects will be addressed in this chapter.

6.1 Planning and achieving carbon neutrality

Carbon neutrality for a higher education institute can be achieved by various means. The major step involves the introduction of mitigation measures, for example in relation to switching to more sustainable technologies or by creating changes in the attitude of carrying out certain operations. Additionally, carbon sequestration options can be utilised or bought in form of offset payments. With the unique position of universities as sites for education, integrating sustainable or climate change-related aspects in research and teaching offers the possibility to ensure a deep connection of staff and students to the reduction of GHG emissions and other actions. (Udas et al., 2018) Those possible pathways need to be planned according to established goals and future visions. On the way to carbon neutrality, there are numerous methods that can be utilised to shape the mitigation plans and to employ a previously assessed emissions inventory. Examples for that are the backcasting approach, as well as different participatory procedures. During the process of creating pathways towards carbon neutrality, main contributors are identified alongside certain limitations that need to be faced. Those aspects will be introduced in the following.

6.1.1 Methods and approaches for becoming carbon neutral

6.1.1.1 Envisioning the pathway

In relation to carbon neutrality, the backcasting methodology is a popular approach for assessing the necessary actions needed to achieve the objective. The method is used to create strategies from the perspective of a future goal, therefore going backwards in time from the future to the present. (Dahal & Niemelä, 2016) Establishing scenarios via backcasting is seen as alternate option to forecasting, where a prediction for the future is made based on the current situation (Miola, 2008).

In general, the method starts with establishing the target – in this case it would be reaching net zero emissions at a specific point in the future. With the future defined and the present condition known, various approaches and actions are tested to determine what needs to be done in order to go from the current state to the desirable future situation. (Dahal & Niemelä, 2016) Different pathways can be assessed in terms of their feasibility and their ability to create the required change. Envisioning a future goal and the necessary steps to reach that point can be seen as a way to build the future by oneself through actions starting from a baseline scenario. Backcasting is found to provide a beneficial method in case of large systematic changes and when the contemplated vision for the future has an intricate characteristic involving many different aspects and opportunities. (Miola, 2008) Considering carbon neutrality, the base case is provided for instance by the calculation of the carbon footprint and the desired future is the decarbonisation goal in a specific time frame. Subsequently, suitable mitigation measures, useful policies and required action plans can be identified and developed via the backcasting approach.

6.1.1.2 Participatory processes

There are two main approaches on how to turn the visions and research for the future into action: top-down and bottom-up processes. Both methods present possibilities on how decisions are made in regard to climate goals and in what way stakeholders of the university could be included in the process of reaching carbon neutrality. The first method, top-down, consists mainly of decisions made by the management level of an higher education institute (Osmond et al., 2013). This includes for example official commitments and policies issued by the rectorate (Zhao & Zou, 2015) or regulations on ongoing operations on campus (Townsend & Barrett, 2015). It is recognised that following this approach will need less time to implement (Disterheft et al., 2012), but could prove less effective on the long run as the decisions could feel like being dictated and would end up not encouraging voluntary commitment by the staff members or the student body (Osmond et al., 2013).

The second approach presents the bottom-up or participatory method. It is designed to support initiatives coming from the student community, individual faculties or employees, empowering the members of the university to share and implement their own thoughts (Disterheft et al., 2012). From that perspective the key stakeholder to take into consideration is the whole student body (Townsend & Barrett, 2015). When carbon neutrality is planned starting from the bottom it could for example feature campaigns by students demanding a systematic change at the university (Zhao & Zou, 2015) or researching and suggesting certain measures or action plans to the institute’s government (Beringer & Adomßent, 2008). Those kinds of actions could lead to a stronger integration and acceptance of mitigation measures but are also identified as more time consuming and less straightforward (Disterheft et al., 2012).

Research on sustainability targets and developments at European universities by Disterheft et al. (2012) showed that including a participatory approach would be the preferred choice of implementation. They stated that only by following a more bottom-up approach a university would be able to achieve the goal of reaching sustainability in combination with pursuing an improved education on the topic. The latter issue would fall short in a primarily top-down approach. Although carbon neutrality is only one aspect of sustainability, achieving it depends also on the performance of the whole university and all the people working or studying there. While the government body of the university should announce decisive emission reduction targets to give the aim an official context, it is said that carbon neutrality will more likely be achieved when everyone involved with the university is supporting the goal and adopting the introduced measures. A participatory approach will most like promote exactly that. (Disterheft et al., 2012)

This assessment is partially shared by the authors of the 'Greening Universities Toolkit', who established pathways on how to implement sustainable strategies most effectively in the working environment of universities. They promoted that a combination of top-down and bottom-up actions would be the best possible and most long-lasting approach. In regard to carbon neutrality, this could for example be done by announcing official mitigation goals via the leadership level of the institution but at the same time supporting student actions and make sure the whole student community is on board. The early participation of students and staff would ensure that the mitigation strategies are being made part of the daily operations at the university by a change in behaviour. Thus integrated, a systematic change would have been achieved that is more independent from goals and policies and therefore more lasting. (Osmond et al., 2013)

6.1.2 Challenges – from carbon footprint to mitigation measures

6.1.2.1 Main contributors

After the goal and the methodology are decided on and the institution has carried out the necessary greenhouse gas emission inventory analysis, appropriate mitigation measures can be defined. The calculated inventory or carbon footprint will help directing the focus to the main contributors and the sectors where the most reduction potential could be achieved. While the results of an emission inventory will strongly depend on the defined scopes and system boundaries (as outlined in chapter 4), it might be possible to pin down the most likely emitters for a university already in advance, for instance based on previous experience shared by institutes who carried out similar calculations. This offers the possibility to plan ahead according to those expectations and decide where the focus should be during the calculation of the footprint, as well as when making commitments.

A study conducted for the Norwegian University of Science and Technology (NTNU) in Trondheim came to the conclusion that one of the biggest factors influencing the amount of released emissions is the question what kind of faculties are part of the analysed institution and included in the calculation of the carbon footprint. It was found that engineering and science departments with laboratories can be associated with the highest individual carbon footprints. This applies to medical faculties and university hospitals as well. Departments responsible for studies of humanities or other social topics tend to cause less emissions. The main reason behind those results is the requirement and procurement of specific equipment and supplies needed in the research facilities, which tend to cause larger emission rates. (Larsen et al., 2013)

The high influence of lab facilities is also pointed out by Klein-Banai & Theis (2013) in their analysis of several higher education institutes in Northern America. In addition, they concluded that the characteristic of the campus plays a major role as well. If the buildings are spread out, the need for commuting between the different locations increases the emissions caused by travelling. Furthermore, a campus with more residential students where the student housing is part of the carbon footprint calculation will have a changed energy consumption profile compared to universities without residential areas: emissions based on waste disposal and water consumption will probably be higher, but commuting will cause less GHG emissions. (Klein-Banai & Theis, 2013)

Several studies point out that the largest share of carbon emissions can be associated with scope 3 of the emissions scale: indirect emissions not caused in relation to the consumption of energy (see Figure 3). This was for example observed by several Finnish universities, where business travels had a high share (Myllykangas, 2020; Tampere University & TAMK, 2020), as well as by a German university where around two thirds of the emissions were caused by commuting and work-related travel (Opel et al., 2017). The other large share can be assigned to the consumption of electricity and heat if the utilised sources are fossil fuel-based and not renewable energies. This is supported by the findings of the carbon footprint calculations for the University of Cape Town, South Africa: over 80% of all emissions associated with the institutions were caused by the usage of electricity as part of Scope 2 (Sangwan et al., 2018). In contrast to that, the Lappeenranta–Lahti University of Technology (LUT), Finland, discovered that almost all of their GHG emissions are part of scope 3 as the utilised energy (Scope 2 emissions) is generated from renewable energy sources and has therefore no assigned emissions (Nurkka et al., 2020). In addition to travelling, the procurement of food for the canteens is another issue that has a large influence on indirect emissions allocated to scope 3 (Nurkka et al., 2020; Sangwan et al., 2018). Being aware of the main contributors will help defining the most appropriate mitigation measures for reaching carbon neutrality.

6.1.2.2 Limitations

Previous attempts of establishing a carbon footprint of a higher education institution revealed some limitations that can occur during the work. First of all, as for instance pointed out by a research team of the University of Turku, there is at the moment no uniformly adoptable strategy for creating a GHG emission inventory for universities. It is possible to broadly rely on guidelines published for companies and other organisations, but for more specific calculations it would be necessary to refer to other standards as well, combining different approaches. Especially in terms of research and education related emissions it is not possible to use already existing calculation tools. (University of Turku, 2020)

This analysis of the current situation is backed up by another research on carbon footprinting for universities: Robinson et al. (2018) stated that there are no internationally adopted guidelines available for higher education institutes. Preferred methodologies, however, are combinations of already existing standards following a mixture of input-output analysis and LCA practices. In accordance with that, universities are seen to often use the methodologies proposed by the GHG Protocol Corporate Standard or ISO 14064-1 as basis for the calculation of their carbon footprint. Lastly, it was found that while emissions represented by scope 3 are most likely the ones with the highest share, they are many times not prioritised in the calculation due to their complexity and subsequently resulting time and cost-consuming estimation, as well as the lack of reliable information. This can lead to a misinterpretation of the situation related to the release of emissions and could hamper the ability to identify the most problematic emitters. (Robinson et al., 2018)

In addition to problems in relation to the calculation procedure, precaution is also necessary when defining mitigation measures for the university to decrease the carbon footprint. The system boundaries need to be carefully defined also in relation to the mitigation approaches to prevent among others a so-called carbon leakage. This term implies that a sector that has to comply with certain limitations to reduce carbon emissions might cause an increase in a neighbouring sector that isn't imposed with mitigation measures as some operations of the first sector are shifted to the other one to elude the restrictions. (Barker & Crawford-Brown, 2015, p. 127) Furthermore, it is possible that a rebound effect could occur, mainly in relation to the usage of energy. This phenomenon is observed when an action becomes cheaper due to saved energy and is subsequently used more often, leading to a smaller amount of reduced energy or even an increase despite the initial mitigation. As the generation of energy is directly related to the emission rate this also affects the amount of released emissions. (Barker & Crawford-Brown, 2015, p. 127)

In terms of defining appropriate mitigation measures on the way to a carbon neutral campus, Townsend and Barrett (2015) identified additional limitations that might occur. By analysing the process at a British university, they came to the conclusion that it is detrimental if there is little knowledge about sustainability or emission-related issues in the community of the institution aiming for carbon neutrality. Missing awareness makes the students and employees less perceptive for action plans and could hamper the success of implemented measures. Furthermore, systematic changes required during the process could be resisted as they do not align with cherished traditions and are therefore opposed. Lastly, the need for funds to support the mitigation measures could encounter resistance as well. Universities have the task to overcome those potential limiters to reach a net zero balance of emissions in the future. (Townsend & Barrett, 2015)

6.2 Exemplary case studies from around the world

For many universities attempting to reach carbon neutrality, the reduction of GHG emissions is only part of a bigger commitment: the aim to become sustainable. This is for example carried out in accordance with the Sustainable Development Goals (SDGs) published by the United Nations (2018) or as part of programs proclaiming the establishment of 'greener' institutions of higher education (see for example the 'Greening Universities Toolkit' developed in cooperation with UNEP by Osmond et al. (2013)). Sustainability consists of three major components: social, economic, and environmental aspects. The latter includes the notion to ensure that operations are carried out in a climate friendly way and therefore also demand the mitigation of GHG emissions.

Whether commitments are officially announced or not, for the universities it is often the calculation of the carbon footprint that comes first, either as necessary prerequisite for defining the baseline scenario before adopting action plans or in form of researchers who are interested in the topic and make the calculations to push the acknowledgment of the impact institutions of higher education have and what could be achieved if the emissions are reduced. While there are many such carbon footprint calculations out there, not as many universities go the next step and actually announce certain targets, like reaching carbon neutrality in a certain year. In the following, a selection of universities with such goals, as well as already carbon neutral institutions will be presented.

6.2.1 Carbon neutral universities

6.2.1.1 North American universities

While more and more higher education institutes make commitments towards carbon neutrality, there is a small number of institutions which have already achieved this goal. Some of the earliest carbon neutral universities can be found in the United States of America. In accordance with the 'American College & University Presidents' Climate Commitment', now a part of a network managed by Second Nature (Second Nature, 2018), a high number of American institutes pledged around 2006 to reach carbon neutrality (United Nations, 2013). So far, nine colleges and universities are listed as carbon neutral, including for example the University of San Francisco and the American University Washington D.C. (Second Nature, 2020). A common point of their achievements is the inclusion of offsetting practices in their calculations, next to initiated mitigation measures featuring the support of more climate-friendly transportation methods by students and staff, as well as the usage of renewable energies and the improvement of energy efficiency in buildings on campus. In addition to the handful of forerunners, the remaining higher education institutes which are part of the network mostly made pledges for a time several years in the future. (Wise, 2020)

The University of San Francisco, for instance, became carbon neutral two years ago, in strong contrast to the original goal set for 2050. The institution names the reduction of water usage and the implementation of micro turbines as a combined heat and power source as main contributors for their achievement. In addition, a carbon footprint is calculated each year and the remaining emissions are balanced with offsetting payments. (USF, 2019) Those actions show that the university seems to favour a top-down approach in their quest for carbon neutrality – the focus is on measures implemented by the university's government and less on smaller actions coming directly from the community.

6.2.1.2 European universities

In addition to the American institutions, there are also universities in Europe holding the title of being carbon neutral. The first of them was the Environmental Campus Birkenfeld of the University of Applied Sciences in Trier/Germany (Disterheft et al., 2012). It was soon joined by the Leuphana University Lüneburg/Germany, which reached carbon neutrality in 2014 after adopting the goal in 2007 (Brüggen, 2020; Opel et al., 2017). One major factor for the Leuphana University is the claim to have made the achievement without the need to buy emission offsets. The carbon footprint calculation includes mainly business travels, utilisation of electricity and water, as well as the operation of the university's canteen and the usage of paper products (Brüggen, 2020) – focusing largely on internal emission sources. The net balance of emissions is achieved via a technology focused approach: their concept for reaching carbon neutrality involves the utilisation of renewable energy sources located on the campus, increased efficiency in the usage of energy and the improvement of heat and cooling demand for buildings. The energy sources are combined heat and power (CHP) plants running on biomethane and photovoltaics. The compensation of the remaining emissions is accomplished based on the negative GHG balance due to providing district heat to a nearby area and delivering renewable energy to the grid from their own solar photovoltaics (PV) and CHP plant. Overall, this procedure of going climate-neutral is mainly a top-down approach as well, as the ones leading the university decided on it and introduced the relevant measures: from small ones, like encouraging a shift in user consumption, to big ones like building a new auditorium and installing new renewable energy sources. (Opel et al., 2017)

Another German university, HNEE Eberswalde, followed the example of the Environmental Campus Birkenfeld and decided to carry out an emission analysis every year with subsequently purchasing the necessary offsetting measures from a specific project supporting climate protection. The carbon footprint includes not only Scope 1 and 2 emissions but also a couple of additional emissions, although not all that are potentially caused on campus, and is calculated mainly based on the GHG Protocol Corporation Standard and ISO 14064-1. (HNEE, 2021)

Furthermore, another case is presented by the 'IUBH Internationale Hochschule'/Germany, an institution that applied for an official certification for their efforts issued by TÜV SÜD. Based on the PAS 2060 standard, this university of applied science followed the additional specifications issued by the German technical inspection association and was awarded with their certification 'Climate neutrality' in 2020. After the calculation of the carbon footprint, the institution developed some small mitigation plans including the reduction of business travels via plane, the reduction of the overall energy usage and the improvement of the institutional car fleet. However, the focus was set on offsetting emissions verified by the Gold Standard. (DFGE, 2020) The initial approach is mainly top-down, but after the accomplishment was made public, a questionnaire conducted within the university's student body revealed that the students were largely in favour of the endeavour and some were calling on the IUBH to further increase the effort and becoming more climate friendly (IUBH, 2020), showing the potential of including bottom-up measures in the future as well.

The introduced examples of carbon neutral universities clearly point out that the means on how the net zero balance of GHG emissions was achieved so far, focusses on the inclusion of offsetting payments and that the initiative, as well as the mitigations plans are mainly derived from top-down approaches. The featured institutions of higher education did not solely rely on offsets but wouldn't be able to achieve the carbon neutrality without them. The implemented mitigation measures are mostly in the range of technological issues like energy efficiency for buildings or the utilisation of renewable energy sources, but especially business travel related emissions seem to play an important role for the universities' assessments as well. Exact numbers on what percentage of the baseline emissions were reduced and what is being offset are, however, often missing from public announcements.

6.2.2 Universities aiming for carbon neutrality

In addition to the smaller number of universities that have already reached carbon neutrality, there is a much larger number of institutions that have made pledges for decarbonising their operations but are still on the way towards net zero GHG emissions.

6.2.2.1 Finland

In a similar spirit as the American alliance of higher education institutes supported by Second Nature and presented previously, there is an initiative from Finnish universities, called UNIFI, pushing towards more sustainable practices in the higher education sector in Finland. The UNIFI theses encourage Finnish universities to aim for carbon neutrality by 2030 the latest, which would be in accordance with the timeframe set by the Finnish government (UNIFI, 2020).

Already before the publication of those theses, there were a handful of institutions pledging their commitment for mitigating carbon emissions. The first Finnish university to proclaim such an endeavour was the University of Turku. In 2019, the goal to become carbon neutral by 2025 was announced (University of Turku, 2020) and they were the first university in Finland to conduct a carbon footprint calculation (Myllykangas, 2020), setting an example for the other Finnish universities. In support of their goal, the university launched a project group concerned with the matter and included the achievement of carbon neutrality in their latest policy program (University of Turku, 2020). The Turku University of Applied Sciences committed to the same year for reaching carbon neutrality, putting both institutions of higher education at the centre of the efforts of the City of Turku who pledged net zero emissions for the year 2029. To already start making positive impacts in terms of managing emissions, the Turku University of Applied Science decided to offset all business travels with the help of local offsetting practices and pricing schemes referencing the European Emission Trading System (ETS). (TUAS, 2020) The whole endeavour of both institutes in Turku seems to largely follow a top-down approach with decisions coming from the universities' administrations and executive boards.

In 2020, the University of Eastern Finland followed the lead of the University of Turku and committed to carbon neutrality in 2025 (Myllykangas, 2020). Already implemented climate actions are the sole utilisation of renewable energies, the implementation of a new recycling strategy and the partial offsetting of emissions (UEF, 2020). The initial decision for going carbon neutral and the setting of the goal was done as a top-down decision, but the ongoing process of creating relevant action plans will involve a more participatory approach for example by including members of the Student Union, as well as offering the possibility for staff and student body of making comments when new decisions are being made. The university also clearly states the wish to calculate a carbon handprint of their research in the future and include the results in the net balancing for the GHG emissions. (Myllykangas, 2020)

A similar notion regarding the incorporation of the handprint approach is supported by the Lappeenranta–Lahti University of Technology (LUT). In addition to their goal of reaching carbon neutrality already in 2024 (Nurkka et al., 2020), the university plans for a carbon negative balance afterwards. This is to be achieved by including the carbon handprint of the institution in the calculation, which will be predominantly made up of the positive influence created by research done at the university in aid of technologies or concepts supporting the mitigation of GHG emissions. The cornerstones of reaching carbon neutrality are the development of a campus that operates in line with sustainability goals and the utilisation of electricity produced by onsite solar PV panels. (LUT University, 2019) Heat pumps, a wind turbine, and the switch towards more energy efficient technologies in buildings are implemented as actions as well, planned by a specifically appointed coordination group and formulated as a roadmap. The starting point for the implementation of mitigation measures was the calculation of the institution's carbon footprint based on the GHG Protocol Standard featuring emissions from all three tiers defined by the guideline. (Nurkka et al., 2020)

In late 2020, the University of Tampere and the Tampere University of Applied Science joined the other Finnish universities in their commitment for net zero emissions and pledged to achieve carbon neutrality by 2030. Even before that, the institutions started the process of calculating their carbon footprint, with focus on emissions caused by the operation of buildings on the campus and emissions related to travelling. Based on this analysis, the best mitigation pathways will be determined and proposed as measures for the universities. The responsibility for carrying out this task lies with a recently established group of experts. (Tampere University & TAMK, 2020) Therefore, the main approach taken by the universities in Tampere is currently applied in a top-down fashion. Additionally, the established goal is in line with the target of the City of Tampere aiming for carbon neutrality in 2030 as well (City of Tampere, 2021).

The Aalto University in Espoo favours a slightly different approach in their climate goals. Net zero emissions are to be achieved in 2030 for the higher education institution and the means of how to reach this target are developed in close collaboration by the Aalto University Board, the staff employed at the university, as well as the community of students and other related stakeholders. This participatory approach will be utilised to create action plans and roadmaps for reducing GHG emissions featuring energy-related issues, emissions caused by commuting and research, but also measures tackling emitters connected to waste disposal and the upkeeping of the university's buildings. Furthermore, Aalto University plans to review the process on annual basis. (Aalto University, 2020)

6.2.2.2 Additional examples from around the world

A German University officially aiming for carbon neutrality is the Ernst-Moritz-Arndt-University of Greifswald. As part of a pilot project the institution tried to develop an approach for a step-by-step transformation of higher education institutes towards more sustainability, with a focus on achieving net zero carbon emissions in the future. The goal is to involve all different parts of a university in the action, from administrative operations and research to the student community and education-related issues. To establish the baseline scenario for the mitigation efforts, a carbon footprint was calculated based on the proceedings of the GHG Protocol Standard for organisations. Two years after announcing the target in 2012, the university had already achieved a cut of emissions by half, mainly due to utilising renewable energy sources. However, there is no target year set for the final goal of carbon neutrality. In comparison to other institutes aiming for a net zero balance, the University of Greifswald emphasises its ability to rely on local offsetting measures based on the ownership of considerable forestry that could be utilised for carbon sequestration. The approach taken by the university features top-down decisions as well as participatory processes. Besides the endorsement of sustainability issues by the rectorate, the establishment of student groups tackling relevant questions is encouraged as well. The cooperation of those different levels is put forward as key factors for succeeding in reaching carbon neutrality. (Udas et al., 2018)

In addition to American and European higher education institutes, there are also universities on other continents aiming for net zero carbon emissions. One of them is the Strathmore University in Nairobi, Kenya. Their proclaimed goal is the achievement of carbon neutrality as first university of the country. The chosen pathway towards the target includes the switch from fossil fuels to renewable energy sources, mainly supported by solar PV panels installed on campus, and the improvement of energy efficiency in the institution's operations. Another key factor was the construction of new buildings in accordance with environmental-friendly building standards and the installation of a managements system for the buildings in terms of lighting and electricity usage. (Strathmore University, 2017)

In 2019, as part of an open letter signed by a great number of institutions and network alliances around the world, the Chinese Tongji University situated in Shanghai pledged to reach carbon neutrality at the latest in 2050 and to increase the inclusion of environmental and climate change related topics in its education programs (O’Malley, 2019). The institution is also the initiator of the China Green University Network, promoting the adoption of sustainability in the daily operations of universities. Accompanying top-down approaches like the retrofitting of existing buildings to improve energy efficiency and the installation of building integrated solar PV panels, Tongji University aims to include the student community in the endeavour as well, for instance by educating about climate change, related mitigation measures, and efficiency in terms of utilising resources. (Osmond et al., 2013)

An exception from the typical pattern of aiming for carbon neutrality can be found in the University of Sheffield/UK. While other universities, like the ones in Finland, make clear announcements of their carbon neutral goals, issued in accordance with the leadership level of the institution, the University of Sheffield so far has not made such pledges. However, in a purely bottom-up effort, the student body formed a network with the aim to encourage the university to commit towards a net balance of GHG emissions in 2025. The group is conducting various campaigns on campus to persuade the rectorate to consider this option and also try to come up with solutions on how the university could reach carbon neutrality. The network has been active for several years now. (CNU, 2021)

7 THE CARBON FOOTPRINT OF UNIVERSITIES

This work was performed in cooperation with the Carbon Footprint Working Group of the University of Oulu. The objective of the work was to provide recommendations for the carbon footprint calculation process. In relation to those recommendations and the already calculated greenhouse gas emissions, the tentative carbon footprint of the campus in Oulu is presented and important, but still missing emissions are pointed out. Additionally, a first comparison to carbon footprints of other universities is conducted. Finally, the carried-out analysis will provide the basis for issuing ideas for promising mitigation measures and actions that would be beneficial to adopt at the University of Oulu. In that way, this work aims to help pushing forward the process of aiming for a carbon neutral campus in Oulu, as many other Finnish universities already do.

7.1 Methodology for assessment of carbon footprint calculation methods

In accordance with the urgency of decreasing GHG emissions and their special role as potential trail blazers in terms of carbon neutrality, universities from around the world have started to calculate their carbon footprint. In some cases, the assessments are carried out with the aim to provide a basis for introducing suitable mitigation measures as presented in the previous chapter. On the other hand, there are a number of higher education institutes where the focus is so far only on the research of approaches without a follow-up of carbon neutral goals for their campuses. The University of Oulu is currently in the middle of the process to calculate its carbon footprint, which is seen as an important step towards reaching net zero carbon emission in the future and increasing the sustainability of the campus (University of Oulu, 2021b). To support that ongoing process, this thesis will identify key points and beneficial methods presented by the research and experience of other universities.

The criteria for the assessment of calculation methodologies include the identification of the used method and whether the approach was based on one of the official guidelines and standards introduced in previous chapters. As it is also important to understand the reasons of why an institute is undergoing such a calculation process, the targets of the universities are explored as well, along with the question who is carrying out the analysis of emissions and which are the identified stakeholders. In relation to the chosen method, other criteria are the potentially utilised calculation tools in combination with the characteristic of the input data. Additionally, an important point to assess are the chosen scopes of emissions, with a special focus on the included indirect and not energy-related emissions (Scope 3), as those are often the ones where the biggest differences can be found. Inspired by a carried-out comparison of CFP-calculation tools by Robinson et al. (2018), the reports and other relevant sources are also searched to discover identified cut-off criteria for the system boundaries as well as emissions that were intentionally left out of the considerations and whether completeness or reliability issues could be detected. The main outcomes of the calculations and proposed mitigation measures are compared to provide a basis for recommendations for the carbon footprint calculation of the University of Oulu. Furthermore, the question is posed if the institutes used handprint calculations during their assessments and whether they included offsetting measures or are planning to use them. Finally, identified benefits and limitations of the methodologies are collected.

The following institutes of higher education were assessed in relation to their adopted carbon footprint assessment methods based on the previously presented criteria (displayed with the main sources used for the analysis):

- University of Turku, Finland (Suominen, 2020; Suorsa, 2021; University of Turku, 2020)
- Turku University of Applied Science, Finland (Paikkari, 2020)
- Lappeenranta–Lahti University of Technology (LUT), Finland (LUT University, 2019; Nurkka et al., 2020)
- University of Eastern Finland (Eskelinen, 2021; Myllykangas, 2020; UEF, 2020)
- University of Jyväskylä, Finland (El Geneidy & Helimo, 2021)
- Leuphana University, Germany (Brüggen, 2020; Opel et al., 2017)
- Energy Institute Hrvoje Požar, Croatia (Jurić et al., 2019)
- Birla Institute of Technology and Science Pilani, India (Sangwan et al., 2018)
- Diponegoro University, Indonesia (Budihardjo et al., 2020; Syafrudin et al., 2020)
- University of Castilla-La Mancha, Spain (Gómez et al., 2016)
- Shikshana Prasarak Mandali's Sir Parashurambhau College, Pune, India (Kulkarni, 2019)
- University of Leeds, UK (Townsend & Barrett, 2015)
- De Montfort University, UK (Ozawa-Meida et al., 2013)
- Norwegian University of Science and Technology (NTNU) (Larsen et al., 2013)

- University of Greifswald, Germany (Udas et al., 2018)
- School of Forestry Engineering, Technical University of Madrid, Spain (Alvarez et al., 2014)

The key findings of the assessment will be presented in the following chapter and a more detailed summary of the comparison in tabular form can be found in Appendix 1. As the assessment of Scope 3 emissions is one of the most discussed topics, a special analysis of the chosen emission categories of the assessed universities is introduced as well. A visualisation of those results can be found in Appendix 2.

7.2 Analysing methods for calculating and handling the carbon footprint of universities

The assessed universities have very diverse backgrounds, timelines and -frames, as well as different motivations for the calculation of a carbon footprint. The majority are European institutions; only three of the sixteen chosen universities are from another continent. Additionally, the focus is also on the approaches of Finnish universities, as their relevance for the University of Oulu can be seen as more significant being situated in the same country and therefore subject to similar common practices, as well as goals and pledges on a national level in terms of carbon neutrality or emission reductions that would apply to the country's institutes of higher education. The earliest of the assessed calculations of carbon footprints were published in 2013 (NTNU, Norway and De Montfort University, UK) using data from 2010 and 2006 respectively. The latest calculations were only adopted at the beginning of this year and depict calculations based on data from the years 2019 and 2020. The differences in timeframe and geographical location offers a broad overview on how universities are currently handling the assessment of carbon footprints.

As outlined in previous chapters, there are internationally accepted guidelines for calculating a carbon footprint on an organisational level, for example the GHG Protocol Corporate Standard or ISO 14064-1. However, as of now, there is no standard specifically tailored to the needs of an institution of higher education, as pointed out by the University of Turku (2020) and Robinson et al. (2018). But the most popular guidelines are used at least partially by the universities. More than half mentioned the GHG Protocol Corporate Standard in relation to their carbon footprint calculations, while only three institutions stated that they were following ISO 14064-1. Especially the application of the scopes defined by the standards seem to be adopted and incorporated in the universities' calculation processes.

The preferred methodology on how to assess the emissions is mainly a kind of hybrid model. Scope 1 and 2 emissions are most often taken care of in an approach based on a life cycle assessment, where the activity data of an action (for example the combustion of fuel by the car fleet of the institution) is multiplied with an appropriate emission factor. Scope 3 emissions on the other hand are compiled by favouring the assessment relying on financial accounts, expenditures, and accounting data as it is done foremost in an EEIOA. Ten out of the 16 assessed universities were adopting this approach for at least part of their identified emission categories, the majority being emissions related to procurements and acquisition of equipment for research, laboratories, and education. For those categories, the emissions are therefore calculated based on the expenditure data, meaning the money spent for the purchase, and fitting emission factors displayed for instance in kilograms of CO_2 equivalents per spent money.

The pioneer in establishing a scheme for using the EEIOA for a university's CFP seems to be the Norwegian NTNU, who developed an approach in the early 2010s (Larsen et al., 2013) and is referred to by other institutions that are trying to assess their performance in terms of emissions (see for example University of Turku, 2020). The main identified benefit of using an EEIOA approach for the carbon footprint calculation is the annual availability of the financial data, facilitating the possibility to easily carry out a calculation process every year. This can help tracking the effort in relation to mitigation measures or goals like carbon neutrality. Additionally, it is found to be less time-consuming and more detailed (Larsen et al., 2013), as well as less costly (Alvarez et al., 2014) and better in covering the whole operations on campus compared to an LCA-based assessment (Townsend & Barrett, 2015). An approach purely based on a life cycle assessment without utilising accounting data for an IOA was only utilised by four of the analysed institutes, among them the ones situated in India and Indonesia. Another key finding is that the analysis of travelling and commuting data is often accompanied by surveys and questionnaires issued to staff and students alike.

Probably due to the lack of fitting tools and the nature of using a hybrid approach, there are not many specifically developed tools for a carbon footprint calculation that are used by the assessed institutions. Beside simple calculation methods, a small number of universities utilised more elaborate models as seen with the harmonised model of the Energy Institute in Croatia (Jurić et al., 2019) or the multiregional hybrid model from the Spanish University of Castilla-La Mancha (Gómez et al., 2016). Chosen tools by the Finnish universities in relation to emission factors or inspiration for calculation approaches include the 'Ilmastolaskuri' published by WWF Finland, the 'Hiilifiksu-laskuri' developed by the University of Finland and VTT's 'Lipasto-laskuri'. However, the majority was developing their own approaches by mixing up several methodologies to get to the most accurate results.

Considering the adoption of offsetting measures, the assessed universities did not extensively take those into account when calculating their carbon footprint. First of all, possibly purchased offsets are most often not part of the actual carbon footprint. Secondly, only four institutions were already officially considering including carbon offsets as part of mitigation plans. Two of those universities have considerable holdings of forest areas which are planned to be passed off as offsets based on improved forestry (see Alvarez et al., 2014; Udas et al., 2018). Another institution already reached carbon neutrality by selling renewable energy produced on campus and counting the saved emissions due to the consumption of this renewable electricity in comparison to electricity generated by fossil fuels as offsets (see Opel et al., 2017). But overall, offsetting measures are not part of the most important considerations for the primary assessment of emissions.

While the carbon handprint is gaining attention especially in Finland, as can be seen by the publication of the guide for calculating a handprint by VTT presented previously, it was not yet adopted by the assessed institutions. Only two Finnish universities, LUT University and the University of Eastern Finland, have expressed their official interest in conducting a carbon handprint analysis in the future in strong relation to their goals of becoming carbon neutral (LUT University, 2019; Myllykangas, 2020).

In terms of presenting the results of the CFP calculation, the main methods are the total number for the whole institution, the emissions per occupied area of the campus, as well as the footprint per individual person, meaning the allocation of the university's CFP to the staff and student body. Less often, the carbon footprint was calculated also for each of the institute's departments or faculties separately (see NTNU (Larsen et al., 2013) and University of Leeds (Townsend & Barrett, 2015)) or per accounting category and for each paid amount of currency (see School of Forestry, Technical University of Madrid (Alvarez et al., 2014)).

Only half of the assessed universities has reduction targets in place in combination with their CFP. Six out of 16 are aiming as far as carbon neutrality – including all the Finnish universities that were part of this assessment. In addition, only the institutions with carbon neutrality targets are found to be committed to calculate the carbon footprint on an annual basis. Institutes without official mitigation targets seem to treat the assessment of emissions as more of a one-time action or at least not as something to be done on a regular basis. The latter are also the universities where the calculation was mainly supported by a research team and not by an official working or coordination group tasked by the institution with the assessment of the current situation as it is for example the case with the majority of the Finnish universities. At those institutes the CFP is deeply embedded in the efforts related to reaching carbon neutrality or improving sustainability on campus.

Depending on the final goals of the carbon footprint calculation, the results are used in various ways. Mainly, they are utilised to raise awareness for climate-related issues and to sensitise staff and student body to the impact of their behaviour when working or learning at the university. The CFP is also detected to provide the opportunity to pinpoint the most problematic areas of operation on campus and therefore to be of help when formulating mitigation measures or designing action plans.

Lastly, the analysed universities identified a number of limitations that came up during the calculation. The most prominent are data issues, for example missing or incomplete information or faulty and outdated emission factors. Two of the often-named emission categories in relation to complications with the acquisition of reliable data are travelling and commuting. This puts the emphasis on the need for developing strategies for better data collection: The more accurate the data, the smaller the error margins and the better the calculated carbon footprint. Furthermore, the setting of system boundaries, specifically in terms of Scope 3 emission, might cause some problems and is at the same time a very important issue. By deciding what kind of emissions should be included in the assessment and which could be intentionally scoped-out, the researchers conducting the calculation have a high influence on the final outcome. This issue will be discussed in more detail in the following chapter.

7.3 Assessment of system boundaries and scopes of emissions

The question which emissions should be calculated as part of the carbon footprint of a higher education institute is strongly tied to the defined system boundary. Emissions from proceedings and actions deemed relevant and important become a part of the final footprint, while others are scoped-out or defined as belonging to another entity. The assessment of the utilised scopes and categories of emissions by the 16 chosen universities is visualised in a table displayed in Appendix 2. The main findings are described below and shown in Figure 9.

7.3.1 Main scopes and categories of emissions identified in the assessment

The majority of the analysed universities follows the definition for the scopes of emissions as outlined by the GHG Protocol Standards. Scope 1 emissions are the ones that were caused directly for example via combustion of fuel on campus, with Scope 2 (energy-related) and 3 (non-energy-related) accounting for the indirect emissions. As previously explained, the main guidelines for the calculation of a carbon footprint demand that all Scope 1 and 2 emissions must be included for a complete assessment. With small exceptions, possibly due to reasons related to the location of the institution (e.g. no heating demand for a university in Indonesia), all of the assessed institutes included all their Scope 1 and 2 emissions. The former often only account for emissions released by the owned car fleet and therefore have usually a very low share. Scope 2 emissions are strongly dependent on the utilised primary energy sources. If renewable energy sources make up the majority, the share of those emissions can sink as low as zero (see for example LUT University (Nurkka et al., 2020)). With the usage of fossil fuels, the end result of the carbon footprint might consist of up to 50% energy-related emissions (see for example Indian college (Kulkarni, 2019) or University in Spain (Gómez et al., 2016)).

The most obvious differences between the chosen categories can be found when analysing the included emissions belonging to Scope 3. The only category unanimously included are the business travels, although the extent varies slightly. Some institutes put their whole focus on flights, others include all modes of transportation (e.g. trains, busses, taxis and leased cars), as well as the emissions associated with hotel overnight stays. Additionally, two universities also calculated emissions of travelling caused by visitors, while four institutions included the travels from student exchanges in their CFP.

A total of six universities did not consider the commuting of staff and students as part of the calculation and four were doing the same for the emissions caused by the consumption and handling of food in the restaurants operating on campus. Notwithstanding those exceptions, these categories are some of the main ones utilised for the calculations. This can be similarly said for emissions related to procurement and the purchase of equipment. 14 out of 16 had at least some procurement categories listed, but when comparing the institutions, the extend of included categories varies greatly. The most popular seem to be emissions caused by the purchase of paper and paper products, as well as furniture, IT-equipment, and office supplies. The universities that had adopted the EEIOA approach for those emissions usually display a higher number of included procurements. The emissions associated with the purchase of equipment is mostly divided into items for research, laboratories, education, as well as chemicals. With the exception of education equipment, which was less often named as individual category, the other items were listed by 13 institutions. Furthermore, more than half of the assessed universities had a specific category for non-energy-related emissions caused by buildings, meaning especially ones that are caused by handling of waste, maintenance, and cleaning, as well as construction.

In addition to those widely adopted categories, the assessment also identified a number of lesser used ones. This includes logistic and transportation of goods, as well as emissions caused by advertisement, communication, publishing, and business or public services. Only a handful of universities adopted those specific categories for their calculation of the carbon footprint. Emissions connected to the investment portfolio of a higher education institution are the one category that was only mentioned by a single institution (University of Jyväskylä, see El Geneidy & Helimo, 2021).

The main reasons given for intentionally scoping-out certain emissions are mostly the allocation as individual footprint or exceptional and non-academic emissions not to be repeated on a regular basis. The latter explanation was for instance used by the College in Pune, India to leave out emissions caused by the renovation of some buildings on the campus (Kulkarni, 2019). Commuting was excluded based on the assumption that it belongs to the individual footprint of staff and students by the University of Applied Science in Turku (Paikkari, 2020) or the University of Leeds (Townsend & Barrett, 2015).

Figure 9 provides an overview of the results discussed in this chapter, while a more detailed list can be found in Appendix 2. Scope 1 and 2 emissions are more or less unanimously calculated by the institutions and the same can be said for at least four categories in Scope 3: emissions related to the management of waste, business travels, procurements, and equipment. In addition to those, four more categories are part of the assessment process of around half of the analysed institutes: commuting, food, maintenance of properties and logistics. At last, emissions allocated to investments, public services, publishing, and advertisement, as well as student exchange and visitor travel are only rarely included.

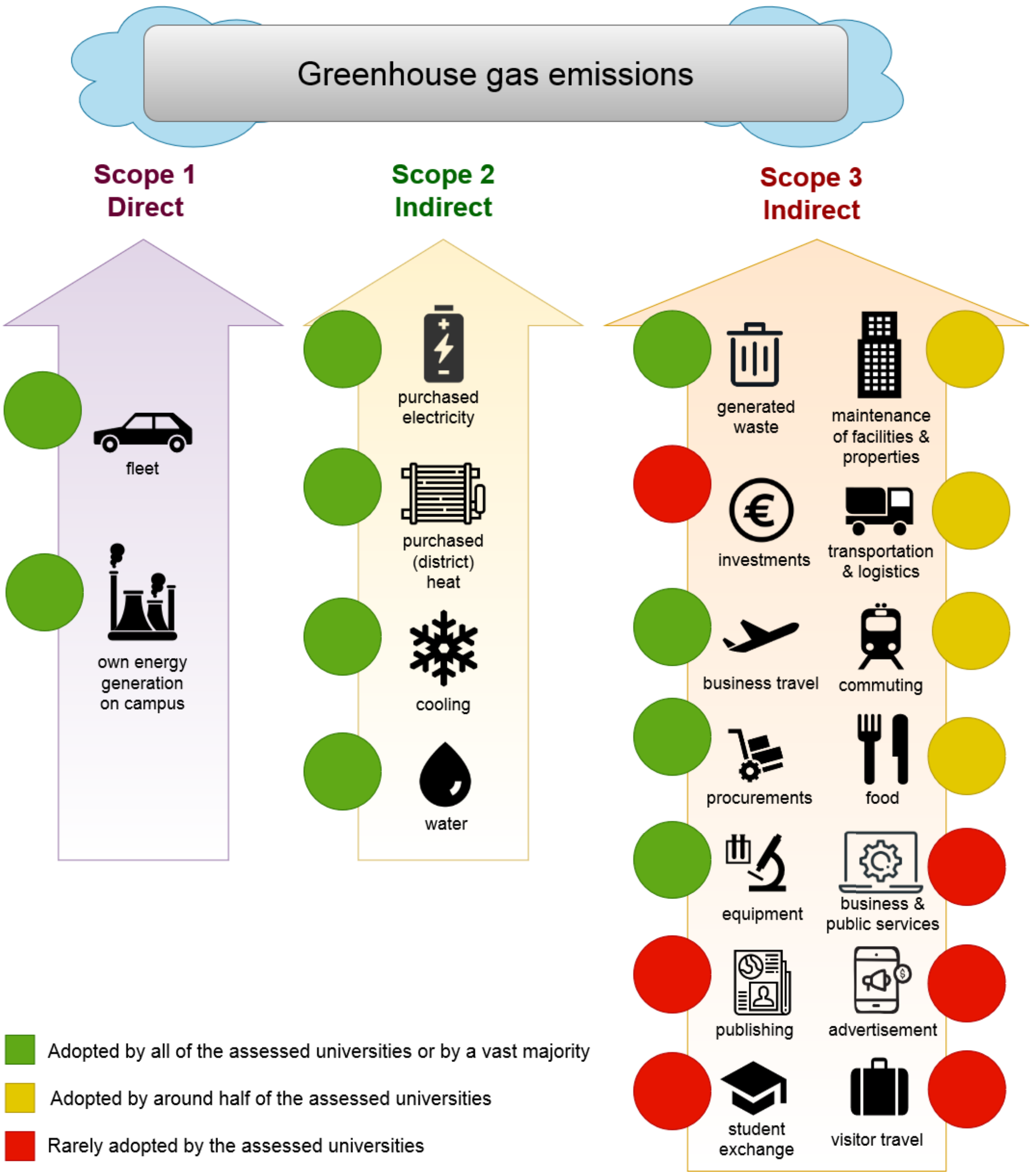

Figure 9. Visualisation of the utilised categories of emissions by the assessed universities.

7.3.2 Recommendations for selecting scopes and categories of emissions for the University of Oulu

As already mentioned above, emissions belonging to Scope 1 and 2 should be calculated for the carbon footprint without leaving out any of them because the main guidelines and widely accepted practices for the organisational level demand those calculations for a complete carbon footprint. The real question that needs to be deliberated are the emissions allocated to Scope 3. The first aspect that might help in this consideration are the categories mainly used by the previously assessed institutions. This would include business travels, commuting of staff and students, food-related emissions, non-energy-related building emissions, as well as the categories of procurement and the purchase of equipment. As the extent of included procured items varies a lot between the assessed institutions, there is not a specific list of what should be included in the carbon footprint. However, given the fact that the most beneficial method for the calculation of those emissions is based on the financial data, it should be practicable and feasible to analyse as many different procurements and bought equipment as possible. Using an extensive definition of the scopes might ensure that the final CFP will more closely resemble the actual footprint and prevent or decrease the occurrence of unreported emissions and underestimations. This will make potentially implemented mitigation measures more effectively.

Secondly, identifying the most significant emitters found by other institutions might help setting appropriate system boundaries as well. The results might differ for the University of Oulu but should at least be taken into consideration, even if it is just to rule out their influence in the end. One example for such a category is the investment portfolio as analysed by the University of Jyväskylä. Although these emissions were only assessed by one institution, they summed up to almost half the share of the university's final carbon footprint. Such a large impact should justify the adoption of this category for the University of Oulu as well, if not as defined part of the total carbon footprint then at least as an important issue to follow-up and consider internally. Other highly emitting categories are already part of the ones chosen due to being frequently mentioned by the assessed institutions.

Lastly, with the analysis including five Finnish institutions, there might be some key categories more often present for those universities as found in the total assessment and therefore maybe of special interest for the University of Oulu. In addition to the opportunity to follow up on the progress of mitigation measures and the identification of necessary actions for reaching carbon neutrality, a carbon footprint could also be used to compare the performance of one university to another. This is especially the case if footprints per student numbers or area are utilised. Even more interesting aspects might be found when institutes in the same country are compared to each other as they are most likely subject to similar constraints or circumstances. From this point of view, it would be beneficial to define the scopes of emissions as similar as possible to ensure a fair comparison. Subsequently, the adding of the emissions caused by student exchange and advertisement, as well as the ones allocated to logistic and transportation of goods should be calculated for the University of Oulu, too, as at least two of the Finnish universities have already taken those categories into consideration. This could warrant a better comparability of carbon footprints between the Finnish institutions.

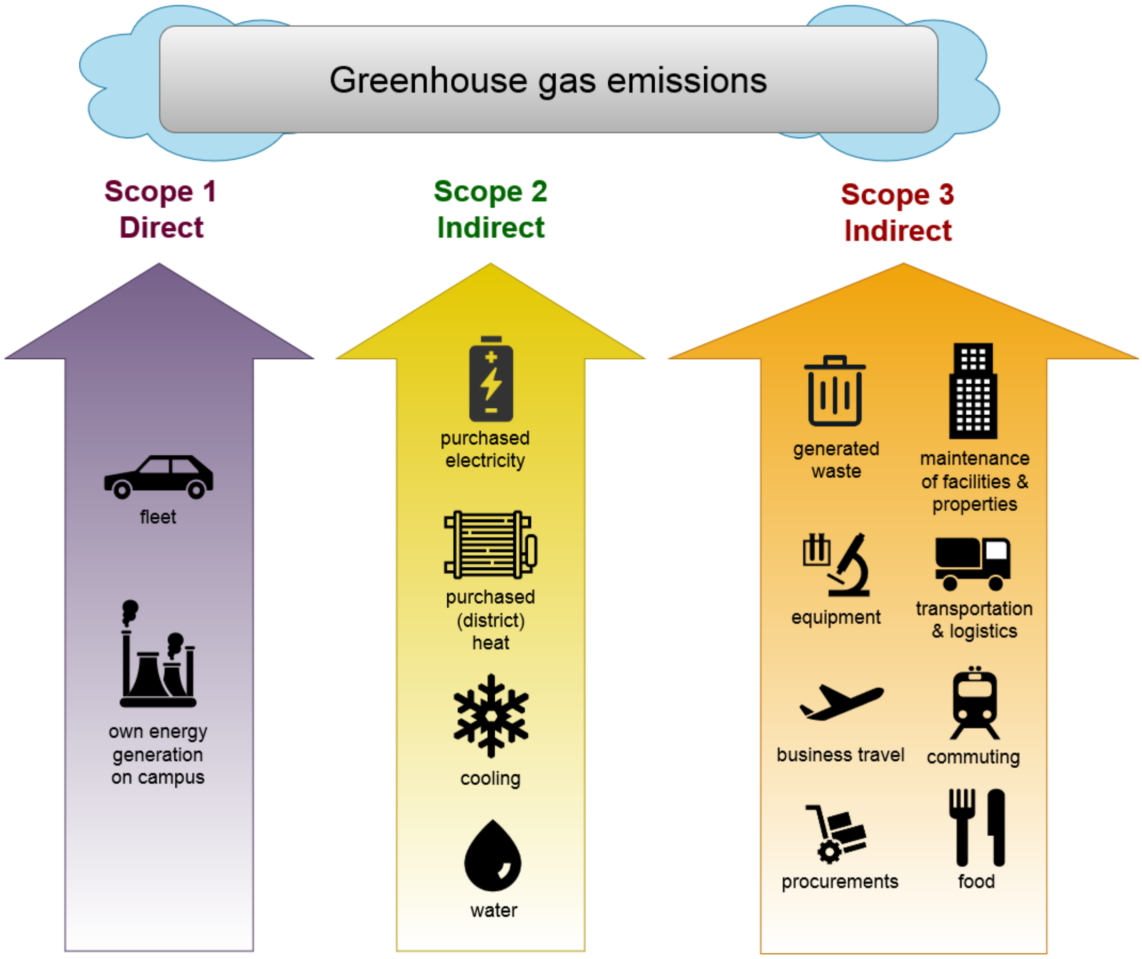

Figure 10. Visualisation of the scopes of emissions recommended to be included in a carbon footprint calculation for a university.

The recommendations based on the analysis of the utilised scopes of the assessed institutions are summed up in Figure 10. While Scope 1 and Scope 2 emissions are included completely, emissions allocated to Scope 3 are limited to the previously identified most relevant categories in contrast to the ones mentioned in Figure 9.

8 DISCUSSION OF THE RESULTS - A CARBON NEUTRAL CAMPUS AND THE CARBON FOOTPRINT AT THE UNIVERSITY OF OULU

Based on a carbon footprint calculation for the year 2021, the University of Oulu recently pledged to reduce its amount of emitted greenhouse gas emissions. Until 2025, the reduction is supposed to at least sum up to 50%. (University of Oulu, 2021b) In accordance with the university's recognition of the UNIFI theses, the next step should consequently be the aim for carbon neutrality in 2030 as encouraged by the theses. This timeline is also requested by the action plans of the Finnish government. (UNIFI, 2020) The decrease of the total carbon footprint is one of the main aspects of the university's strategy to create sustainable campuses. Therefore, the institute aspires to calculate the footprint on an annual basis and develop mitigation measures based on the results. (University of Oulu, 2021b) With the assessment process already underway, it is possible to create a tentative carbon footprint for the University of Oulu and provide a first analysis in relation to the assessment results introduced in the previous chapter. This will be presented in the following, along with an assessment of the potential action plans for decreasing the emitted emissions.

8.1 Tentative carbon footprint of the University of Oulu

The tentative CFP was created based on the assumptions made for the scopes of emissions and the already available numbers for some of the chosen categories. The utilised data presents the year 2019. With the University of Oulu planning to start the monitoring from the level of 2021, the current calculations will eventually only provide the concept and calculation method to be used for the desired carbon footprint. But due to the still ongoing exceptional situation with the Covid19-pandemic and the potential impact on usage and consumption on campus, the availability of older footprints might be beneficial to put the latest results into perspective.

The total amount of emissions currently sums up to 10 449 t CO_2e. To ensure a better comparability with other universities, the CFP can also be presented as 0.618 t CO_2e/person with regard to the number of students and staff members (16 900 (University of Oulu, 2021a)), as well as 0.071 t CO_2e/m^2 considering the area of the buildings belonging to the campus and the share actually used by the university

(148 266 brm² (SYK, 2019)). Figure 11 shows the visualisation for the tentative carbon footprint.

At the moment, the calculation strongly depends on information provided by Suomen Yliopistokiinteistöt Oy (SYK), the owner of the buildings belonging to the university's campus. The company issued the data for the energy- and non-energy-related emissions of the buildings, including the categories maintenance, construction, as well as the demand and related emissions for district heating, cooling, the usage of water, and electricity. The reported values are mainly based on consumption data multiplied with appropriate emission factors. The emission factor for the heat supply was defined in consultation with the responsible provider, Oulun Energia, in consideration of the mixture of used primary fuel. (SYK, 2019) The majority of the electricity used by the University of Oulu is purchased via the university's framework agreement provider Hansel Ltd. This electricity is generated only with renewable energy sources, the emission factor used in that category equals zero (SYK, 2019). However, as it can't be said with absolute surety at the moment that all the purchased electricity is renewable, the electricity contracts are in need of a closer inspection for the final results of the carbon footprint.

The carbon footprint working group at the University of Oulu is responsible for the remaining categories. The emissions related to waste include the transportation, as well as its handling and are based on transportation distance and weight of the produced waste in relation to emission factors issued by the calculation tool 'Y-HIILARI' of the Finnish Environment Institute (SYKE). Emissions created by business travels feature trains, rental cars, flights, and hotel overnight stays. For the modes of transportation, emission factors published by SYKE and VTT's calculation tool 'LIPASTO' in travelled km per kg of CO_2e were applied to the travelled distances booked and reported via CWT, the company managing the business travels for the university. The hotel stays were based on daily emission factors and the number of nights the hotel was used as reported by Hansel Ltd. This organisation also provided the necessary information for the procurement category, which at the moment only consists of purchased IT-equipment, meaning laptops and mobile phones. The emissions were not calculated based on an input-output approach, as previously identified as preferred approach by other universities, but using the number of purchased items, their expected service life and annual emission factors per item provided by the Finnish company Motiva. (M. Hilli, personal communication, 2021)

As can be seen in Figure 11, the highest share of emission is by far the district heating, followed by the business travels. The rest of the already assessed categories have in comparison a much smaller impact. Important, but still missing categories in Scope 3 are commuting of staff and students, food-related emissions and purchased equipment for research and laboratories, as well as additional subcategories for the procurement emissions. Furthermore, the carbon footprint does so far not include potential Scope 1 emissions. Despite the assumption that those might be rather small compared to other categories, the major guidelines unanimously demand the consideration of Scope 1 for a consistent footprint calculation. Therefore, further analyses need to be conducted for those emissions as well.

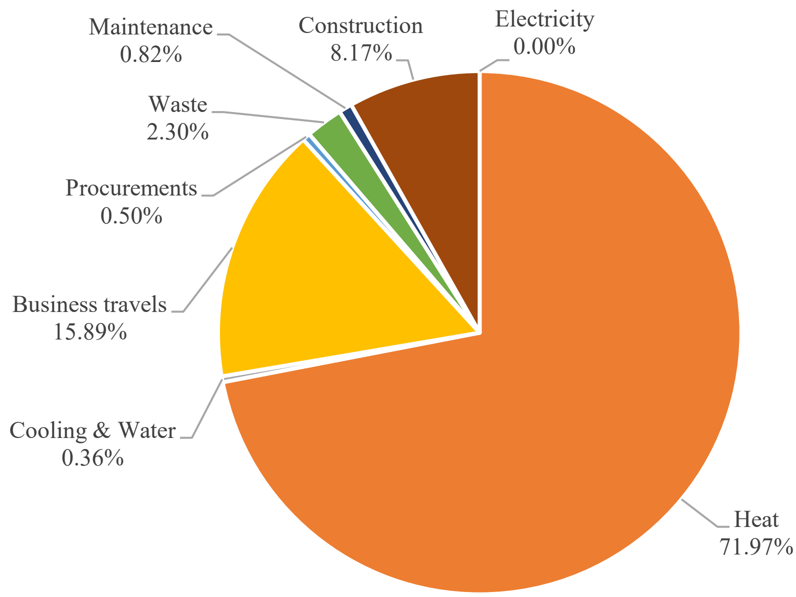

Figure 11. Tentative Carbon Footprint: University of Oulu (2019).

An important information in regard to the data provided by SYK for building-related emissions is the fact that starting in 2020 the company has been compensating all emissions from managing their properties with Gold-Standard certified offsets (Lassila, 2020). This comes in addition to the fact, that with the purchase of electricity solely generated from renewable energy sources, the Scope 2 category of utilised electricity was already set to zero. Subsequently, the scope of energy-related emissions would amount to almost nothing. However, for displaying the proper carbon footprint it should be noted that bought offsets should only be applied afterwards to the released emissions and should not directly influence the characteristic of the CFP. This is a point on which all the main guidelines and standards agree. The purchase of renewable energy and the subsequent zero emissions attributed to the electrical energy is not affected by this practice as it is not categorised as offset. Displaying the actual CFP, following the advice given by most of the popular guidelines, should therefore be the preferred practice. This is also beneficial for preventing the neglect or underestimations of certain emissions because of the offsetting – mitigation should always be a goal despite offset payments. While displaying the actual CFP is certainly important from that point of view, it is also necessary to keep the purchased offsets by SYK in mind when planning for carbon neutrality to avoid double counting of offsets or emissions.

8.2 Comparison with other universities' carbon footprints

With major components still missing from the tentative carbon footprint of the University of Oulu, a real comparison with other institutions is not yet entirely possible. However, a few indicators can already be assessed and might help putting the current results into perspective. To give an overview of the carbon footprints of other Finnish institutions of higher education, Table 3 depicts their total footprints as well as the values in relation to students and staff members, as well as the utilised area.

For one, it seems that the impact of the emissions from district heating have right now (see Figure 11) and probably will also have in the final version of the University of Oulu's carbon footprint a very large share, also in comparison with other universities especially with Finnish institutions (see Figure 12 and 13). This again presses the point that the offsets purchased for the buildings' emissions by SYK should not be included right away, as displaying those emissions will help to understand their relevance, although the university's direct influence on the emissions released due to the generation of the district heat is limited as it is the responsibility of the energy provider. Despite that, another Finnish institute, LUT University, chose to include the offsets for the buildings purchased by SYK beforehand (Nurkka et al., 2020), leading to a quite small footprint in comparison. Already now, with only the tentative CFP to compare to, this institution has a smaller footprint than the University of Oulu and not only in total numbers, but also when examining the results per people or area. With the displayed carbon footprints for 2019 in Table 3, the LUT University is the only one to take SYK's offsetting into account. This is clearly visible when comparing the final values. The University of Eastern Finland has the second lowest carbon footprint, excluding the University of Oulu's tentative result, but the total CFP is already more than seven times larger than the one from LUT

University. However, with regard to the footprints per person and area, the difference is slightly less with around three times the amount. But it shows that dismissing the Scope 2 emissions, meaning especially the ones allocated to the purchase of district heat, because of purchased offsets might lead to the omission of a significant portion of the Finnish institutions' CFPs and to an entirely different appearance of the final footprint. This could have unwanted effects on the planning of potential mitigation measures if those are only developed based on the results of the CFP.

Table 3. Carbon Footprint of Finnish institutions in 2019.

Carbon Footprint University	Total CFP ($t\ CO_2e$)	Staff & Students ($t\ CO_2e$/person)	Area ($t\ CO_2e/m^2$)	Reference
LUT University [i]	2 054	0.307	0.031	(Nurkka et al., 2020; Römpötti & Kasurinen, 2014)
University of Eastern Finland [ii]	16 000	0.878	0.101	(Eskelinen, 2021; Myllykangas, 2020)
University of Jyväskylä [iii]	40 818	2.4	0.24	(El Geneidy & Helimo, 2021; SYK, 2018a)
University of Turku [iv]	21 680	0.955	0.113	(SYK, 2018b; UTU, 2021)
University of Oulu [v] **(tentative)**	10 449	0.618	0.071	(SYK, 2019; University of Oulu, 2021a)

[i] Number of students and staff members: 6 683 | Area: 67 022 m^2

[ii] Number of students and staff members: 18 260 | Area: 158 000 m^2

[iii] Number of students and staff members: 17 000 | Area: 170 000 m^2

[iv] Number of students and staff members: 22 700 | Area: 192 100 m^2

[v] Number of students and staff members: 16 900 | Area: 148 266 m^2

As previously mentioned, the highest share of emissions in the carbon footprint of the University of Jyväskylä is the investment portfolio, this is also depicted in Figure 12. Including those emissions leads to a total carbon footprint of 40 818 t CO_2e in 2019 and is therefore the highest of the analysed Finnish universities so far. In that context, it is also important to be aware of the fact that with the different characteristics of the institutions, especially concerning the size of the campus area, the number of students learning and staff members working at the university, the total carbon footprint might not show every detail. While the total CFP and the footprint per person of the University of Jyväskylä are currently around four times higher than the tentative ones from the University of Oulu, the CFP per area accounts to only a bit more than three times the one from Jyväskylä. This is an indicator for the different nature and shares of the various emission categories. Additionally, it shows the usefulness and importance of the area- and people-related footprints for comparisons between institutes. Following the large share of emissions due to investment, the CFP of the University of Jyväskylä features high amounts of emissions related to procurement and the buildings. The remaining categories account for a maximum of 6% each. At the moment, it also looks like the share of business travels calculated for the University of Oulu along with the impact of district heating emissions might be much larger compared to the results published by the University of Jyväskylä. However, the future finalisation of the tentative carbon footprint will provide the opportunity for a more detailed assessment and comparison.

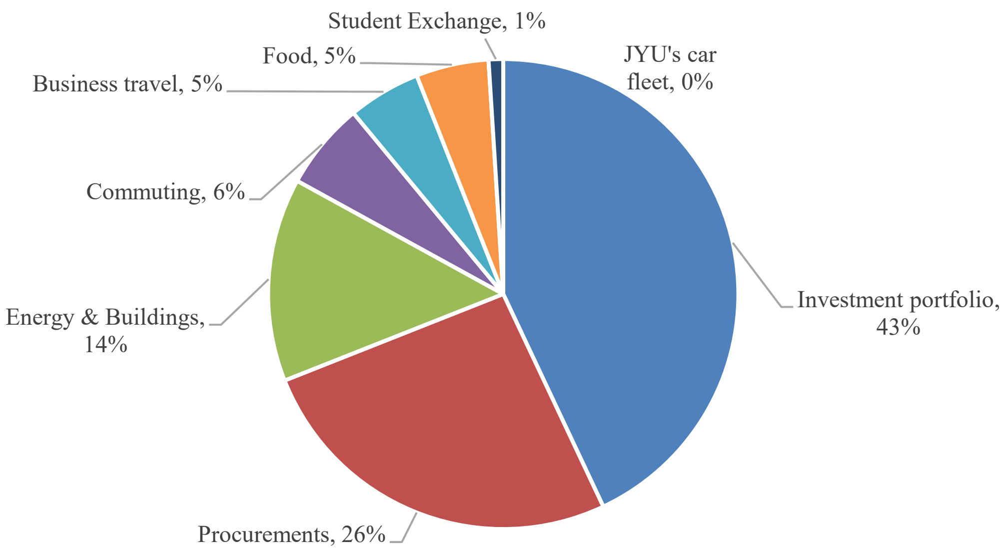

Figure 12. Carbon Footprint of the University of Jyväskylä in 2019 (based on El Geneidy & Helimo, 2021).

Another university to take a closer look at is the University of Turku, as this institution was one of the first in Finland to conduct a calculation process for GHG emissions. In comparison to the CFP of the University of Jyväskylä and the tentative footprint of the University of Oulu, they did not include the exact same scopes of emissions, especially leaving out commuting, food, and the investment portfolio. Based on those system boundaries, the total carbon footprint is around half the one from Jyväskylä and at the moment still double the one calculated for the University of Oulu. The relations of the allocated carbon footprints are similar to that of the total numbers, with a slightly advantageous proportion of student and staff numbers, as well as area to the total emissions for the University of Turku compared to the institutions in Jyväskylä and Oulu.

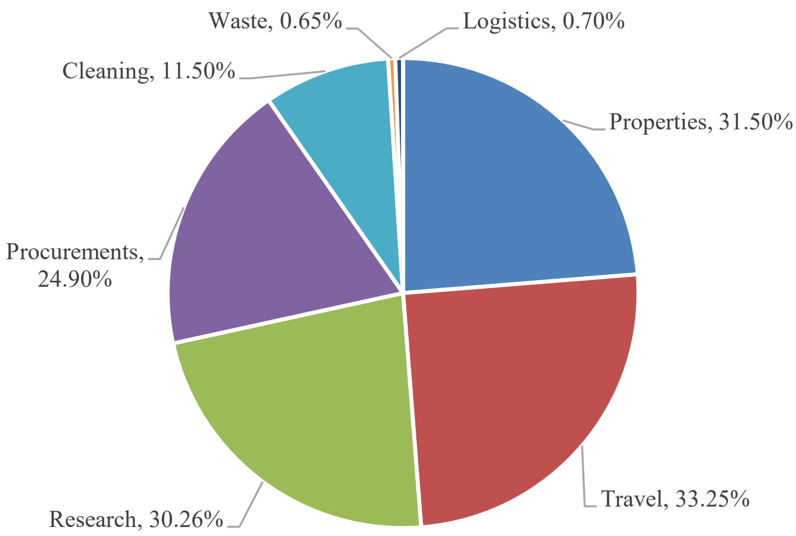

Figure 13. Carbon Footprint of the University of Turku in 2019 (based on UTU, 2021).

Figure 13 shows the University of Turku's carbon footprint as pie chart. The largest shares can be attributed to business travels, research equipment and properties. The clear differences in the share of specific categories (e.g. business travel) when set side by side with the other two universities is an indicator for the importance of transparent reporting and publishing of final results. When the included emissions for each category are publicly known, it will be easier to understand where the major differences came from and could then also increase the understanding of the stakeholders involved with the university. The differences in the displayed categories between the carbon footprints also raise the suggestion that for better comparison, the chosen categories and relevant values should be coordinated, at least for institutions in the same area or country. This supports the notion presented earlier that the carbon footprint calculation for the University of Oulu should take more influence from the approaches taken by other Finnish institutions than from universities in other areas.

Despite the obvious differences in the carbon footprints, the final results could in the end prove to be much more similar if every institution would include the same categories and emissions, as well as complementary approaches and input data, as they are situated in the same country and a large part of the emissions related to buildings are mostly handled by the same company (SYK). Concerning the input data, this is especially true in terms of utilised emission factors, as those are prone to high variations. A combined effort for uniform methodologies might therefore be desirable. After all other interfering factors are eliminated, the real differences between the institutions might be easier to assess and analyse. This could subsequently also help in adopting appropriate mitigation measures by getting more inspiration from other institutions with similar background and CFP results. The utilisation of the footprint in relation to climate action plans is investigated in more detail in the following chapter.

8.3 Mitigation measures in combination with the carbon footprint

8.3.1 Popular actions proposed by assessed institutions

Based on the calculation of the carbon footprint, as well as the exposed contributors and their shares, many of the assessed institutions had either recommended mitigation measures to be applied or had reported on already established actions. The main ideas include the introduction of more energy saving methods and a push in energy efficiency, for instance with the introduction of LED lighting systems. Moreover, refurbishment of older buildings or areas with significant shares of energy-related emissions were considered as well. New travel guidelines are supposed to address the high contribution of emissions of flights: The utilisation of trains for short distance travelling and an increase in the number of virtual meetings are two of the named measures. In relation to the emissions caused by the handling of waste and other relevant considerations with reference to the sustainability of the campus, some institutions were planning to improve their recycling strategies. This could also be influenced by suggested changes in procurement policies.

More technical orientated mitigation measures include the installation of renewable energy sources, such as solar PV systems, on campus. This was for example done by the LUT University (LUT University, 2019). A major help with identifying appropriate mitigation measures could be provided by additionally calculating the CFP for each department or faculty as seen in the calculation approach of the NTNU (Larsen et al., 2013) and the University of Leeds (Townsend & Barrett, 2015). That concept could help to pinpoint the areas where the mitigation measures should be especially applied to, because of them having the highest shares in the respective departments. In addition, it might provide more understanding for the different characteristics of the various faculties and subsequently indicate that different mitigation strategies are needed for each area to adequately support the aim towards a carbon neutral campus.

8.3.2 Integration of stakeholders

Despite the small number of universities that directly addressed the issue of relevant stakeholders, the ones who did all named the student body and the staff as important factors and groups of interest. It can therefore be seen as necessary to involve the people early on in the process of mitigating emissions by raising their awareness of the matter. One attempt might be found with conducting surveys in relation to the carbon footprint. Others could include campaigns to promote more cleanliness on campus with the aim to lower the need for maintenance and related emissions as suggested for the University of Applied Science in Turku (Paikkari, 2020) or the introduction of meatless days in the canteens proposed by the responsible research group of the University of Eastern Finland (Myllykangas, 2020). Those actions in particular require a strong support from the university's community and highlight the importance of early involvement to ensure the success of the planned actions.

The notion that the carbon footprint could increase the awareness and therefore also the willingness of people to incorporate environmental consideration into their actions is supported by a study conducted on the concept of adopting calculations of emissions on the way towards sustainability. Loyarte-López et al. (2020) assessed the impact of a regularly calculated CFP on an organisation over two years and found that the awareness of the impact created by the employees was made more tangible by the publication of the footprint, which led to an increased number of possibilities to reform habits and include more environmental-friendly practices in daily work. The carbon footprint was for instance responsible for a better understanding of the impacts created by waste and energy consumption, proving the practical value of regularly conducting and communicating assessments of emissions.

8.3.3 Offsetting and compensation

After the application of relevant and promising mitigation measures, the next step to consider could be the purchase of offsets or the support of research for investigating sequestration options on campus. The former was for example adopted by the University of Eastern Finland by offsetting flight emissions from business travels (Myllykangas, 2020). Those actions could help to already decrease total emissions now, while long-term mitigation strategies are still under development. However, as already touched on previously above in relation to offsets purchased by SYK for building-related emissions, offsetting measures should not be part of the carbon footprint but can certainly be supported by first calculating the emissions in form of a footprint and determining the actual number of needed offsets. If offsets are purchased, the goal should also be to reduce the necessary amount of those compensations over the years along with the reduction of the total emissions. This is a concept that is also promoted by the University of Jyväskylä (El Geneidy & Helimo, 2021).

Another option to countervail the released emissions brought into play by the University of Jyväskylä, is a so-called internal compensation program. With this proposal, the institute's research group is drawing inspiration from similar measures already adopted by ETH Zürich, University of Gothenburg and Yale University. (El Geneidy & Helimo, 2021)

Internal compensation systems consist of funds filled with money coming from fees or taxes internally defined by an organisation for certain actions carried out by employees. In combination with sustainability goals, the fees can apply to actions that cause damage to the environment or are known for releasing high amounts of emissions, for example in form of prices for GHG emissions. The money collected from the paid fees can subsequently be used to support environmental-friendly procedures. (Addicott et al., 2019; El Geneidy & Helimo, 2021) The Yale University developed a system that introduces an internal carbon price for organisations (Addicott et al., 2019) and also adopted such a system for itself: departments have to pay for each tonne of emitted energy-related emissions. This carbon tax was found to encourage energy saving significantly. (Plumer, 2017) The ETH Zürich and the University of Gothenburg introduced compensation payments for business travelling via flights. At both institutions the fund financed by this money is used to promote and sponsor research and educational projects that favour climate-friendly actions or will directly help decreasing the emissions caused by the universities. (Högberg, 2021; Mazzotti et al., 2019) Based on the positive experience in those institutions, it is certainly worth researching possibilities of adopting a similar program for Finnish universities.

8.3.4 Mitigation measures at the University of Oulu

The University of Oulu has recently announced a number of actions related to decreasing the emissions caused on campus. Many conform with the ones suggested by the assessed institutions. One focus are energy-related emissions that are aimed to be combatted with increasing energy efficiency and applying saving measures. In addition, the installation of a 210 kWp solar PV systems on campus was already undertaken as well. For travelling and commuting emissions, the University wants to encourage the usage of more environmental-friendly modes of transportation such as trains, busses, and bicycles. Moreover, the amount of waste is supposed to shift towards recyclables and less burnable waste, as well as a general decrease of garbage also including food waste. This proposal goes hand in hand with the goal to apply more sustainable procurement policies, favouring for example extended lifetimes of equipment. (University of Oulu, 2021b)

Based on the calculations of the carbon footprint that are currently underway, the already proposed mitigation measures could be further refined and laid out in more detail, fitted to the final results of the assessment. Especially the raise in awareness for staff and student body could benefit from that and gain a more prominent role in the University's strategy. This could for example come along with challenges for reducing waste or energy usage with final rewards at the end for participating departments or student groups. Another potentially interesting approach could be research into the sequestration options offered on campus for example by the University's botanical garden in Linnanmaa. Lastly, the adoption of an internal compensation system as considered by the University of Jyväskylä could provide new options for channelling money to projects that would favour a decrease of emissions on campus or end up creating a carbon handprint for the University. Investigating the possibilities of such a system as explained above could provide additional benefits and incentives on the way towards a carbon neutral campus.

8.4 Summary of recommendations for the calculation of a carbon footprint

The key findings of the assessment of applied methods by 16 European and Asian universities for analysing the amount of released emissions provide the basis for recommending appropriate ways of calculating the carbon footprint at an institution of higher education. First of all, it would be beneficial to use the outline and main rules published by the main standards as guideline for the procedure. Especially the usage of the definitions for the scope of emissions should be founded on the ones from standards like the GHG Protocol Corporate Standard, as it was also already done throughout this work. Due to the popularity of this guideline, it might be easier to find common ground with calculations published by other universities and a comparison might be enabled.

The best method for a CFP calculation seems to be a hybrid model, combining the most beneficial practices of an approach inspired by life-cycle assessment or environmentally extended input-output analysis. The number of institutions preferring that approach and the identified benefits speak certainly in favour of it. Following this method, Scope 1 and 2 emissions are mainly calculated based on activity data and appropriate emissions factors, while especially categories featuring procurement and purchased equipment will rely on financial accounting data and fitting emissions factors. An important advantage of using financial data for the University of Oulu could be the easier repetition of the calculation process on an annual basis, which would be necessary to follow-up on the progress in relation to the defined goals for the reduction of emissions.

Recommendations for the inclusion of specific scopes and categories of emissions were already discussed at length above. Figure 10 in chapter 8.2.2 sums up the selected categories: In addition to all emissions belonging to Scope 1 and 2, the most relevant emissions are allocated to business travels, commuting, food, procurement and equipment, logistic, as well as the handling of waste and the properties. Although other categories were not defined as the most relevant ones, it is also encouraged to conduct internal calculations for some of those emissions. In relation to net zero carbon emissions it is beneficial to be aware of as much details as possible when it comes to the impacts caused on campus. And while they may not be part of an officially published CFP, maybe to preserve a common framework defined in cooperation with other universities, following-up on additional emissions would definitely not be of any disadvantage to the institution.

Currently, the University of Oulu issued a goal for a reduction of the emissions caused on campus by 50% until 2025. To comply with the UNIFI theses and the aims formulated by the Finnish government it will be necessary to also set a timeframe for achieving carbon neutrality soon afterwards. Assessing not only the carbon footprint but also a potential carbon handprint might be helpful in that endeavour. Despite a lack in official adaptions of this practice for a whole organisation as displayed in the key findings, the interest towards this practice is certainly on the raise and developing new approaches for the calculation therefore favourable. Another important aspect in terms of reaching net zero emissions is the early involvement of the student body and the staff members, some of the main identified stakeholders. Carbon footprint and also the handprint can be applied to raise the awareness of those stakeholders and help define new guidelines for common procedures at the university supporting the shift to a carbon neutral campus.

Considering the consistently encountered and reported limitations especially in relation to the quality of the utilised information, a necessary recommendation is the development and improvement of strategies for collecting data and the selection of appropriate accompanying factors and variables used in the calculations. With more consistent procedures it could be possible to achieve the reduction of potential errors and decrease the amount of unavailable or incomplete data, leading to a more accurate CFP.

Lastly, mitigation measures and potential action plans should be developed in relation with the final carbon footprint of the university, as those calculations will provide valuable insight on the areas and activities on campus that cause the highest emissions, indicating where improvements should be primarily made. As mentioned previously, a carbon footprint calculated separately for each department or faculty might prove beneficial in that way as well. Moreover, in accordance with the most commonly applied guidelines, potential offsetting measures should not be part of a carbon footprint but can surely be considered nonetheless in combination with the reduction of emissions. Finally, in addition to the already introduced action plan of the University of Oulu, taking new ideas for decreasing emissions, such as an internal compensation system is also recommended to realise a sustainable and carbon neutral campus.

9 CONCLUSION AND RECOMMENDATIONS FOR FURTHER WORK

The reduction of greenhouse gas emissions and the increase of sustainability throughout today's society are important goals in light of the ongoing climate change and its resulting consequences for the earth. International treaties such as the Paris Agreement, action plans developed by national governments and goals implemented on a much smaller scale as for example the Finnish UNIFI theses are increasingly paying attention to this fact. Institutions of higher education are found to play a significant role in the endeavours for combatting climate change. With their potential for research, their already available knowledge, and their role as educator of the future generation they are seen as obligated to contribute to aims for net zero emissions proposed by the aforementioned pledges on all levels of society. Furthermore, they should act as role models by implementing mitigation measures themselves.

Actions towards carbon neutrality are supported by the calculation of the carbon footprint. There are already several standards and guidelines available today that can provide the necessary support for such a process. The definition of the relevant scopes of emissions and the general outline of the approach on how to adopt the assessment of the GHG emissions can be based on methods for example indicated by the GHG Protocol Corporate Standard. But because of the sensibility of the emissions to the characteristic of the assessed organisation, it is also necessary to make adjustments for the specific cases such as universities, as there are currently no readily available guidelines custom-fitted for them.

This thesis project assessed the approaches utilised by 16 institutions of higher education from Europe and Asia to analyse commonalities and differences in the procedures of calculating a carbon footprint. Based on a number of criteria, such as utilised standard, adopted method, included scopes of emissions and specific system boundaries, as well as discovered benefits and limitations in relation to the applied process, the goal was to issue recommendations for ongoing or upcoming calculation procedures to ensure the selection of the most appropriate method, as well as to increase the uniformity of such endeavours. The analysis emphasised the point that there is not one single approach used by everyone but a fast variety of different, albeit sometimes very similar methods. The preferred approaches vary between the scopes of emissions: Scope 1 and 2 are often based on activity data paired with emission factors, while Scope 3 emissions are acknowledged to be best calculated based on an EEIOA approach. In accordance with that, it was concluded that the recommended method is the utilisation of a hybrid-model that combines the best of both practices, as it is already applied by a number of the assessed educational institutions.

Special attention during the assessment of the utilised approaches was also paid to the included categories of emissions, with Scope 3 featuring the largest variety. Based on the analysis it was possible to pin down a number of categories that are included by the majority of the evaluated universities: Especially the categories of business travelling, procurements, purchase of equipment, commuting and food, as well as logistics are most often taken into consideration. In addition to the inclusion of all found emissions belonging to Scope 1 and 2, those are the categories that should be at least analysed for Scope 3.

In relation to this analysis, the tentative carbon footprint of the University of Oulu was assembled based on already available information and data. With a total CFP of 10 449 t CO2e or 0.618 t CO2e/person the institution currently has a smaller footprint than other Finnish universities, but when compared to the recommendations a large portion of emissions is still missing, explaining the comparatively small size of the tentative result. Therefore, further assessments need to be conducted on that point.

The results of the analysis further suggested that there are a number of popular mitigation measures that are proposed by various universities. The developed action plan by the University of Oulu on the pathway to a sustainable and potentially carbon neutral campus features many of the ideas also issued by some of the assessed institutions, including for example aims for energy saving or the support for commuting via public transport. In addition, it was found that a stronger participation of the most effected stakeholders, meaning students and staff members should become an important part of the university's strategies. In addition, more measures such as internal compensation programs could be taken into consideration. The CFP could help with those aspects by raising the awareness for climate-related and sustainability issues.

One of the main limitations of this work was sometimes the relatively low availability of information or the lack of detail published by some of the higher education institutions in terms of their calculation procedures. Even universities aiming officially towards carbon neutrality lack on occasion a clear and conveniently to find presentation of their carbon footprint and the utilised calculation methods. This is also an aspect that should be considered by the University of Oulu when the calculation of the CFP is finished and the reporting of the results is discussed.

With the newly published statement of the University of Oulu to decrease the greenhouse gas emissions by 50% until 2025, the necessity to provide a consistent calculation and final carbon footprint clearly has a priority. Based on the results found by this thesis work, a further development of the university's CFP should be conducted. In addition, it would be beneficial to form a calculation framework in collaboration with the other Finnish universities to achieve a consistent methodology enabling the comparison of results and the cooperation in defining appropriate mitigation measures. Furthermore, the at the moment still missing emission categories of the University's tentative carbon footprint need to be calculated. At the same time, a consistent practice needs to be developed to provide the possibility of an annual calculation following the initial final CFP to control the effect of mitigation measures and map the process towards the mitigation goal. This could be extended in the future towards reaching net zero emissions. Lastly, despite the already existing guidelines for carbon handprints of products, the assessment showed that there is currently no university that utilised this kind of calculation. It can be said that there is a big potential that needs to be further developed on that front which might provide further means for creating a carbon neutral campus.

The goal of this work was to support the ongoing calculation of the carbon footprint at the University of Oulu and provide the basis from which a common framework for the assessment of emissions could be established based on the best practices found in methods utilised by other institutions of higher education. It is expected that the collected information of the literature review and the presented results of the comparative assessment can help mapping the emissions and achieve the mitigation goals defined by the University of Oulu.

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Appendix 1. Table of comparison: Methodologies and approaches for the calculation of a carbon footprint at institutions of higher education

Table 4: Methodologies and approaches for the calculation of a carbon footprint at institutions of higher education

Criteria Institution/Organisation	Reference	Method	Guideline/ Standard	Targets/ Motivation	Who is responsible for calculation?	Calculation tools & Input and Output data	Additional information	System boundary & cut-off criteria	Scope of emissions (focus on scope 3)	Scoped-out emissions	Quality of data	Identified stakeholders	Main outcomes	Utilisation of handprint	Proposed mitigation measures	Identified benefits	Identified limitations
University of Turku (UTU), Finland	(University of Turku, 2020) (University of Turku, 2021) (Suorsa, 2021) (Suominen, 2020)	EEIOA (inspired by NTNU) -> especially for equipment/ Procurement-categories		Carbon neutrality in 2025 Annual CFP calculation started in 2018	project group under the University's Steering Group for Sustainable Development (Carbon Neutrality Working Group)	e.g.: WWF ilmastolaskuri, Lipasto-laskuri (VTT), Hiilifiksu –laskuri (Helsingin yliopisto)	Data used for 2018, 2019 and 2020		Scope 3: food, travelling + commuting, equipment procurement, maintenance, logistics, waste, buildings (construction, waste, refrigerants) Scope 2: mainly buildings -> heat & electricity (0%), cooling	After calculation: commuting, food-related emissions			2019: 21,680 t CO2e 33.25% travelling (especially flights) 31.5% Properties 30.26% Research (mainly research equipment & chemicals + laboratory materials) 2.49% procurement 1.15% maintenance/ cleaning 0.7% logistics 0.65% waste	Not specifically done so far.	strategy and policy programme for 2021–2030 includes sustainable development goals 100% RES SYK (property owner) is compensating emissions -> drop in CFP expected District heating provider Turku Energia aims for carbon neutrality as well -> influence on CFP		
Turku AMK, Finland	(Paikkari, 2020) – bachelor's thesis	Delimitation & calculation principles inspired by University of Turku approach Commuting -> staff survey (answers from 12%) Travelling -> Travel invoices Equipment: chemicals, laboratory, research | Procurements | Waste | Logistics | Cleaning -> EEIOA based on income statement	Scopes from GHG Protocol Corporate Standards	Carbon neutrality in 2025	Bachelor's thesis	Hiilifiksu –laskuri (Helsingin yliopisto), EEIOA (euro-based carbon footprint assessment) -> same as University of Turku Hotel overnight stay -> emission factors in Hiilifiksu-laskuri Equipment & Porcurement + Services: Factors used in from of kg CO2/€	Used data from 2018		Buildings (energy – electricity + heating) Travelling (flights, hotel stays, boat trips, car use, no trains (VR is carbon neutral)) Food (canteen food & coffee) Procurements (office supplies, prints, clothing IT, …) Chemicals & Laboratories Research equipment Services (e.g. health service, meetings, IT service, events) Waste Cleaning Logistics Own vehicles	community lunches/food (although third highest) staff commuting (calculated, but excluded) -> declared as part of individual footprints	aim of the calculation: not accurate values but information on scale of GHG emissions and most significant sources		46% buildings 26% travelling 9% services 8% procurements 6% research equipment 3% waste + cleaning 2% chemicals + laboratory equipment <1% logistics	No.	Energy savings Switch to renewable electricity sources Decrease travel emissions with virtual meetings Promote biking Everyone's actions (e.g. support cleanliness -> less cleaning service needed + supporting veggie food) Turku city forests as carbon sink Reforestation Local compensation model of the city of Turku		Incomplete data (e.g. travelling -> no data for travel in country of destination, missing distances) Outdated emission factors Missing data for taxi trips High share of guesses and estimations
Lappeenranta-Lahti University of Technology LUT, Finland	(LUT University, 2019; Nurkka et al., 2020)		GHG Protocol Corporate Standard	Carbon neutrality in 2024 -> carbon negative afterwards (development of carbon negative roadmap)	Team of sustainability research experts	e.g.: WWF ilmastolaskuri			Scope 3: food, commuting, business travel, publishing, waste, construction, research, education, advertising, maintenance Scope 1: LUT fleet Scope 2: 100% RES & District heating compensated by SYK				1% scope 1 0% scope 2 99% scope 3 33% Food 22% Commuting 20% Business travel 8% Publishing 3% Waste 3% Construction 3% Research 3% Education 3% Advertising 1% Maintenance 1% LUT fleet	Yes. (planned)	Green campus research Own solar PV systems + wind turbine + air-to-water heat pumps 100% RES LED lighting system		
University of Eastern Finland (UEF)	(Myllykangas, 2020; UEF, 2020) (Eskelinen, 2021)	Similar to UTU Buildings: calculated by SYK (includes heating, electricity consumption, water, waste and refrigerants, construction for new and refurbishment projects, maintenance) Travelling: invoices (hotel, flight, ship, bus, rental car, train) Restaurant operation: only food considered for CFP		Carbon neutrality in 2025 CFP reported annually until 2025	6 research groups (one for each emissions category)	Emission factors: electricity (100% RES) & DH provider, water supply company Construction & cleaning: euro-based Electronical waste – WWF calculator Procurements + AV equipment + office supplies: euro-based IT equipment + furniture – WWF calculator.	Data input: 2019 Two locations: Joensuu & Kuopio		Facilities Procurements Travel Campus restaurants Laboratories Science Communication printing + copying services research & teaching material freight clothing gifts promotional materials other small purchases, materials, goods		Identified as rough estimations of emissions (improvement needed) much room for improvement in availability and accuracy	Student Union University Properties of Finland Ltd. Compass Group Hansel Restaurant service provider	16,000 t CO2 21.8% Heating 21.4% Labs 16.5% food service 16.2% flights 10.1% procurements 7.5% other travel 6.4% other emissions from real estate (Student exchange: 4.4% of travelling CFP)	Maybe for research & education	Offsetting -> flight emissions 100% RES Recycling consumer plastic waste Improving energy efficiency New traveling guidelines Meat-free days cafeteria		Sampling errors (e.g. travelling data) Errors due to inaccurate emissions factors

		(others is in building CFP) Laboratory: EEIOA for procurements & WWF ilmastolaskuri for waste				Books for library – VTT calculation & euro-based Travelling: emission factors mainly from Hiilifisku-laskuri								
University of Jyväskylä, Finland	(El Geneidy & Helimo, 2021)	Travelling: invoices & receipts		Climate neutrality in 2030	Sustainability for JYU – working group		Data input: 2019		Scope 1: JYU vehicles Energy & buildings Procurement Business trips, home trips, ie trips between home and university, and student exchanges Food Investments, ie the university's equity, fixed income and fund investments through asset managers	40,818 t CO2 (2019) 43% investments 26% procurements 14% energy & buildings 6% commuting 5% business travels 5% food 1% student exchange <1% JYU vehicles	No - Positive effects were not considered.	Net zero impact approach -> mitigation & compensation at the same time (incl. JYU's vehicles, procurement, business and student trips and investments) -> Traditional payment or internal compensation switching to zero-emission energy sources Update procurement and travel policy to minimize climate and environmental disadvantages		
Leuphana University, Germany	(Brüggen, 2020; Opel et al., 2017)	Includes exergy analysis, integral modelling and planning of campus Emissions and primary energy consumption		Target achieved (carbon neutral in 2014)	Opel et al.				Business travel Fleet Electricity + Heat Water Paper usage Food	44% commuting 15% heat (space heating + hot water) 23% electricity 18% business travels	No.	biomethane-powered CHP & solar PV systems high-temperature aquifer thermal energy storage refurbishment of old buildings offsetting -> excess energy from CHP and solar PV to nearby district		
Energy Institute Hrvoje Požar, Croatia	(Jurić et al., 2019)	Self-developed harmonised model Emissions = activity data x emission factor	In line with ISO 14064 & GHG Protocol Corporate Standard		Juri´c et al.	Self-developed Croatian Model based Bilan Carbone® model developed by ADEME	Data input: 2017	10 source categories (Bilan Carbone model): Energy sources Non-energy sources (manure, industrial processes) Input of material and services Packaging Transport of persons Transport of goods Direct waste Use stage (consumption during usage of product) End-of-life Capital goods	Scope 1: consumption of car fleet + leakage of refrigerants in cooling system Scope 2: purchased electricity from grid + heating from district heating Scope 3: Downstream: end-of-life waste (non-hazardous) Upstream: direct waste + wastewater, commuting, business travels, visitor travels, transport of goods, capital goods (e.g. furniture, laptops), input (e.g. food, paper, equipment)	650.6 t CO2 59% business travel + commuting 22% electricity + heat	No.		harmonised model offers alignment with data from different domains – national and international context for organisations	
Birla Institute of Technology and Science Pilani, India	(Sangwan et al., 2018)	Activity data x emissions factors LCA approach Food habits, travelling and commuting based on staff and student survey	ISO 14064		Sangwan et al.	Ecoinvent database for emissions factors LCA approach utilising Umberto NXT universal software & Ecoinvent v3.0 database	Data from 2014/15		Scope 1: direct emissions of university owned facilities: burning of fossil fuel in electric generator and own fleet Scope 2: indirect energy emissions of purchased electricity, heat, or steam Scope 3: other indirect emissions: travel and commuting, transportation of goods, paper usage, various waste, food, refrigerants, chemicals, institutional procurements needed for research/labs/… (e.g. electronics, furniture, glassware)	Scope 1: 1.1% Scope 2: 50% -> mainly due to high need for air-conditioning Scope 3: 48.9% Scope 3: 68% travel related + commuting students 12% food 10% procurements	No.	Telecommuting instead of travelling	Raising awareness with CFP among staff and student body Inspiration for other institutions to follow up on CFP calculation	assessment + availability of data

Diponegoro University, Indonesia	(Budihardjo et al., 2020; Syafrudin et al., 2020)	Academic and Non-Academic Sectors separately	GHG Protocol Corporate Standard		Budihardjo et al. & Syafrudin et al.	Academic sector: CFP via activity data and emission factors (following IPCC) Non-academic sector: interviews, observation and university's record			Scope 1: clean water treatment activities Scope 2: electricity usage activities Scope 3: transportation, wastewater, solid waste treatment activities in the campus environment -> for two areas: academic & non-academic sector				Academic sector: Biggest emission source: electricity usage (scope 2) Second biggest: transportation (includes commuting) Biggest emitter: engineering faculty Non-academic sector: 1. electricity 2. wastewater + water supply	No.	Mapping of faculties and buildings to identify individual shares of emissions recommendation for institution: increase of energy savings		limited availability of information for non-academic activities
University of Castilla-La Mancha, Spain	(Gómez et al., 2016)	hybrid environmentally extended input–output model (EEIOA) in a multiregional framework starting point: consumption-based inventory			Gómez et al.	cradle-to-gate expenditure data (university's budget) 160 categories for expenditure data emissions data from World Input-Output database & Spanish coefficients	Period: 2005–2013	Downstream: embodied emissions in directly and indirectly used input Upstream: embodied emissions in direct inputs produced and used by institution					60% energy-related (24% electricity-related) 15% business travelling, including hotels, restaurants, inland transport, air transport Indirect emissions account for up to 80%	No.	changes in procurement policies reduction of energy and material usage no specific footprint reduction plan	EEIOA: useful for gathering complex & non-material contributions to CFP Hybrid-model: enables usage of more accurate regional data instead of averages	Data availability
College in Pune, India	(Kulkarni, 2019)	Bottom-up calculation (process-based method) Department & total footprint based on questionnaire-survey method outlined by (Robinson et al., 2018) + adapted to local background 1.) Setting boundaries (organisational & operational) & identifying activities 2.) data collection -> mainly based on interviews, questionnaires, and invoices (water, electricity) 3.) Calculation 4.) Reporting, Communication			Kulkarni	bottom-up approach & consumption-based individual evaluation of each academic department sum of individual footprints makes total footprint CFP = activity data x emissions factor	Base year: 2015/16		Scope 1: Use of LPG, transport of staff, human breathing, travel of staff + educational trips Scope 2: Electricity Scope 3: Waste (degradable & non-degradable), paper, ink, toners, events, chemicals, electronic appliances	non-academic activities: maintenance of non-movable assets such as buildings	Difficulties in relation to scope 3 emissions	Departments & faculties Student body Staff	Scope 1: 28% Scope 2: 48% Scope 3: 25% electricity (35%), biodegradable and non-biodegradable waste, stationary paper, 7%, use of chemicals in the laboratories (5%), paper for official purpose (12%), LPG (3%) and transport (27%) departments of Chemistry (22%), Computer Science (16%) and Physics and electronics (14% each) electronic appliances (16%), paper (13%) and daily commutation of the students and staff (33%)	No.	Researching strategies for carbon sequestration on campus	Also includes emissions without financial data (a possible problem with EEIOA) Bottom-up approach: accurate CFP possible with well-defined boundaries	high cost, labour intensive, difficulty in defining boundaries and truncation error Scope 3 issues: boundary setting, data availability and calculation reliability
University of Leeds, UK	(Townsend & Barrett, 2015)	EEIOA for scope 3 – based on two region input output model 1.) estimate output changes to final demand by sector 2.) assess direct & indirect economic change within IO model (financial transactions between sectors) 3.) assess emissions: sector output changes (output x emissions factor €/output unit) 4.) sum emissions from all sectors -> final emissions = final demand	Scopes are adapted from GHG Protocol Corporate Standard	reduce Scope 1 and Scope 2 emissions by 35% from a 2005/06 baseline by 2020/2021	Townsend & Barrett	Scope 1 & 2: emission factors advised by Defra/DECC Interviews with university staff working with procurements	Scope 1 & 2: 2010/11 University expenditure data: 2010/11	Dominant in institutional CFP: Scope 3 emissions If not: too much is excluded -> error in definition of system boundary	Upstream emissions of purchased goods Business travel Upstream transportation and distribution of inputs Indirect impacts of electricity generation Disposal of waste generated in operations Operation of leased assets not included in Scope 1 or Scope 2	Private activities: Commuting, energy use at private halls of residence and the disposal of products purchased in the university Upstream emissions of purchased capital goods Visitor travel Student's home trips to and from university accommodation downstream (gate-to-grave) emissions -> processing, use and disposal of sold goods and services		Key stakeholder: student community Staff Leadership level of university	Scope 3: 51% Scope 1: 18% scope 2: 31% Scope 3: 6% raw materials + chemicals 2% Food & Drink 1% Paper & Publishing 8% Manufactured Products 9% Machinery & Computers 13% Utilities + Construction 5% Transport & Communication 2% Business Services 5% Public Services Highest emitter: medicine and engineering faculty	No.	Reduction of Scope 1 & 2 emissions based on Carbon Management Plan aided by knowledge of hotspots for emissions	EEIOA: readily available financial data, therefore easy and less time consuming Accounts cover majority of campus proceedings -> increases accuracy Advantage compared to process-based analysis Organisational decision making is positively influenced by CFP Helps finding win-win situations in line with sustainability approach Annual availability of financial data simplifies updating of CFP	CFP comparison strongly affected by chosen system boundaries & missing transparency in terms of used method and categories Current policies (e.g. for procurement) at universities might hinder changes recommended by CFP

De Montfort University, UK	(Ozawa-Meida et al., 2013)	consumption-based carbon footprint hybrid top-down/bottom-up approach: bottom-up primary data used for activity and consumption processes top-down data for emissions factors (national averages)	GHG Protocol Corporate Standard + ISO 14064	annual progress reports based on CFP Reducing scope 1 & 2 emissions by 43% until 2020	Ozawa-Meida et al.	Emission factors derived from: Defra/DECC (Greenhouse Gas Conversion Factors for Company Reporting) Bottom-up data from staff/student travel surveys (voluntary, annual) Procurements via EEIOA matrixes	Scope 1 & 2: base year = 2005/6	Building energy: Direct emissions from University buildings and equipment Travel: Direct and indirect emissions from staff and student commutes, business travel, students' trips home and visitor travel Procurement: Upstream supply chain (indirect) emissions of the goods and services consumed by the University (excluding energy and travel)	Gas use buildings (supply, combustion), grid electricity use (direct + indirect), life-cycle emissions biomass combustion in buildings, energy use in private halls of residence, fleet (combustion + well-to-wheel), staff & student commute, student travel (international + UK-based), visitor & business travel, procurement (incl. waste & water)			34% energy use 29% transport-related 38% procurement activities Scope 1: 6% Scope 2: 15% Scope 3: 79% Scope 3: 3% Upstream energy supply 9% private halls of residence 18% staff + student commuting 8% student trips home 3% business + visitor travel 38% procurement	No.	Sustainability Strategy & Carbon Management Plan supported by CFP: energy policy, green travel plans, waste management policy, emission reduction	scope 1 to 3 emissions can be covered by consumption-based inventories	Some data limitations & uncertainties (e.g. in relation to travel & commuting data of students, visitor travel data)
NTNU, Norway	(Larsen et al., 2013)	EEIO modelling based on Financial Accounts Hybrid-model for Scope 1 & 2	Scopes are adapted from GHG Protocol Corporate Standard		Larssen et al.	Financial data matched to modelling categories	Data input: 2009 financial accounts	Total CFP & Per Department and faculty CFP	Energy: electricity, district heating, heating oil Travel: employees, students, car allowance Buildings: Construction & Maintenance Equipment: Science &Technology, computers, machinery Consumables: office & teaching supply, food, books Services Others			19% Energy 19% Buildings 19% Equipment 16% Travel 11% Consumables 5% Services Lower CFP per student: Social Science and Humanities Higher CFP: Natural Science, Engineering, Faculty of Medicine	No.	Identified need for individually fitted mitigation measures for departments /faculties modifying opening hours and demand of heat, ventilation, and lighting usage of alternative energy sources Influencing users: no lights in unoccupied offices, turn off standby modes of office computers and machinery, minimizing need for maintenance activities Travel-related: video conferencing	EEIOA: enables identification of different structures in CFP of various sectors reliable + accurate quality in short time easily updated annually	lack of detail (limit to specific equipment categories) -> therefore need to use hybridized model (especially for energy-related emissions) might be affected by pricing issues and variations, can't account for economy-of-scale effects (fixed relationship between procurement data and emissions)
University of Greifswald, Germany	(Udas et al., 2018)		GHG Protocol Corporate Standard	CFP shall support transformation towards carbon neutrality (no time frame)	Established entities: sustainability coordinator (rectorate level) senate commission on sustainability non-formal environment management group		Only CO_2 emissions!	system boundary effected by organizational structure, character of activities, involved stakeholders, sources of direct and indirect emissions	electricity, heating, and business-related travels by the university staff	commuting			No.	carbon reduction, carbon offsetting and mainstreaming sustainable actions via teaching and research Offsetting: University's own forests are used as carbon sink		
School of Forestry Engineering, Technical University of Madrid, Spain	(Alvarez et al., 2014)	Organization-Product-Based-Life-Cycle Assessment -> compound method based on financial accounts Based on cradle-to-gate life cycle Top-down approach 1.) corporate CFP 2.) process mapping for allocation of CFP contributions Harmonized input–output tables used for energy intensities	Scopes are adapted from GHG Protocol Corporate Standard		Alvarez et al.	based on the consumption land-use matrix developed by Wackernagel et al. (2000) + added sections for generated wastes and managed lands IPCC direct emission factors Scope 3: allocating categories of financial accounts to categories (416) provided by the used model	Data input: 2010 CFP per € purchased and per student & per consumption and accounting category GHG: Carbon dioxide, methane, nitrous oxide		all upstream emissions + land-use emissions + waste generated from downstream emissions Scope 1: Direct emissions from natural gas, gasoil, petrol Scope 2: Electricity Scope 3: Materials (office supplies, electronic equipment), construction materials, restaurant & hotel services, cleaning & maintenance, travelling, logistics, agricultural & fishing services, forestry resources, water footprint, waste			Scope 1: 8 % Scope 2: 33% Scope 3: 59.0%	No.	CFP used as basis for carbon management plan Offsets -> sustainable forest management & agricultural practices (included in CFP)	Avoiding of many chances to overlook indirect emissions with the usage of financial data from purchases low financial and time costs usage of model offers comparability of different institutions (same scopes and boundaries) & combination with ecological footprint simple and easy to understand transparent	challenges in quantifying scope 3 emissions errors occurring in regard to international imports and geographic location of model Data not updated annually Uncertainties in regard to the scale of economies (data available for national level)

Appendix 2. Table of comparison: Scopes of emissions

Table 5: Overview for the scopes of emissions utilised by the assessed institutions of higher education

Scopes	Scope 1	Scope 2			Scope 3														
	Direct Emission	Indirect emissions			Indirect emissions														
	Fleet, own energy generation, etc.	Electricity	Heat	Cooling, Water, Steam	Business travels	Commuting	Student Exchange	Visitors' travel	Food	Equipment - Research/ Laboratory/ Chemicals	Procurements	Properties/ Buildings (non-energy-related)			Investment portfolio	Logistics/ Transportation of goods	Publishing	Advertisement/ Communication	Business & Public Services
HEIs												Waste	Maintenance	Construction					
University of Turku, Finland						calculated, but excluded			calculated, but excluded										
Turku AMK						calculated, but excluded			calculated, but excluded										
LUT, Finland																			
University of Eastern Finland																			
University of Jyväskylä, Finland																			
Leuphana University, Germany											only paper usage								
Energy Institute Hrvoje Požar, Croatia																			
Birla Institute of Technology and Science Pilani, India																			
Diponegoro University, Indonesia																			
University of Castilla-La Mancha, Spain																			
College in Pune, India																			
University of Leeds, UK																			

De Montfort University, UK								calculated, but excluded											
NTNU, Norway																			
University of Greifswald, Germany																			
School of Forestry Engineering, Technical University of Madrid, Spain																			

Legend: Green – included by the institution

Red – not included by the institution

Yellow – category is included in an insufficient way compared to the other institutions

Blue – calculated but excluded from the final carbon footprint